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(12) **United States Patent**  
**Chen et al.**

(10) **Patent No.:** **US 9,491,341 B2**  
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(54) **MOBILE DEVICE AND OPTICAL IMAGING LENS THEREOF**

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Taichung (TW)

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(73) Assignee: **GENIUS ELECTRONIC OPTICAL CO., LTD.** (TW)

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(21) Appl. No.: **14/186,804**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

**H04N 5/225** (2006.01)

**G02B 13/00** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H04N 5/2254** (2013.01); **G02B 13/0045** (2013.01)

(57) **ABSTRACT**

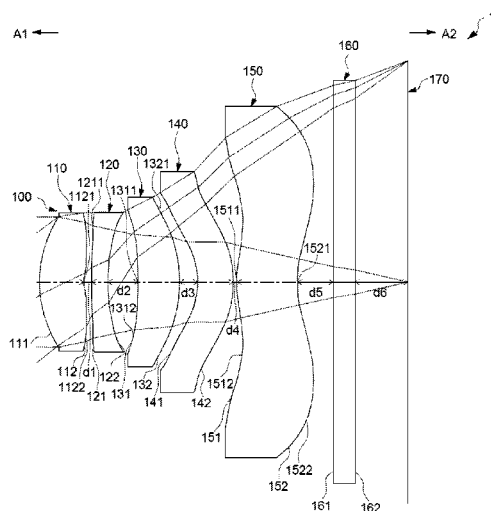
Present embodiments provide for a mobile device and an optical imaging lens thereof. The optical imaging lens comprises five lens elements positioned sequentially from an object side to an image side. Through controlling the convex or concave shape of the surfaces and/or the refracting power of the lens elements, the optical imaging lens shows better optical characteristics and the total length of the optical imaging lens is shortened.

(58) **Field of Classification Search**

CPC .... G02B 9/60; G02B 13/0045; G02B 13/18; G02B 13/002; G02B 3/04

USPC ..... 359/764, 763, 714, 708  
See application file for complete search history.

**18 Claims, 24 Drawing Sheets**



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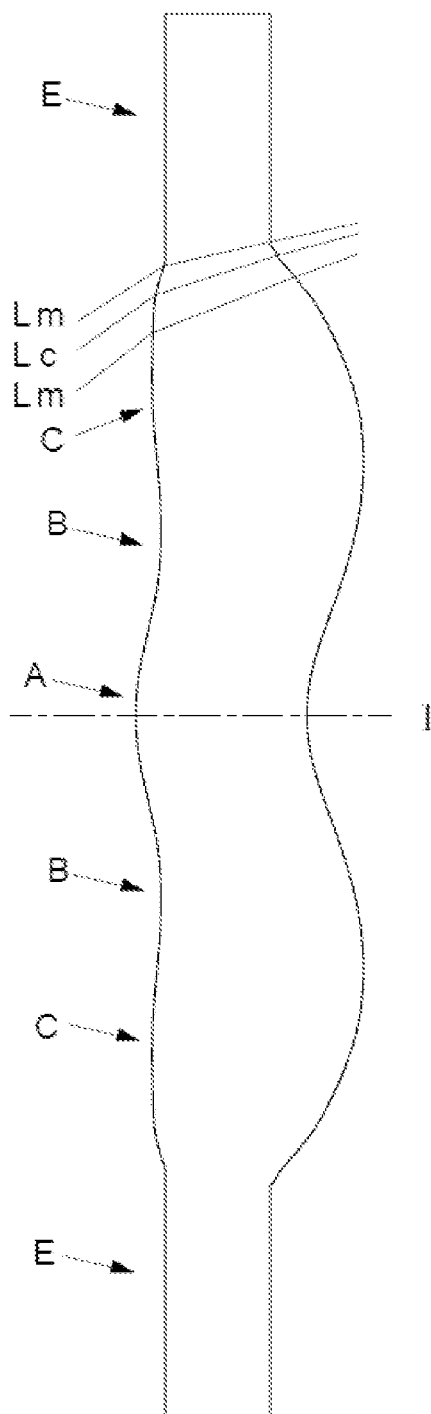


FIG. 1

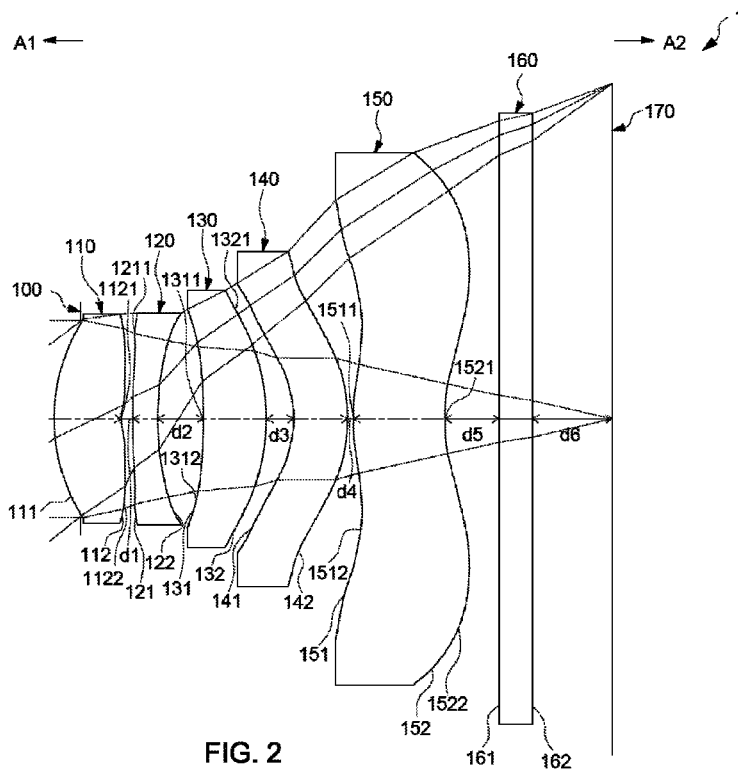


FIG. 2

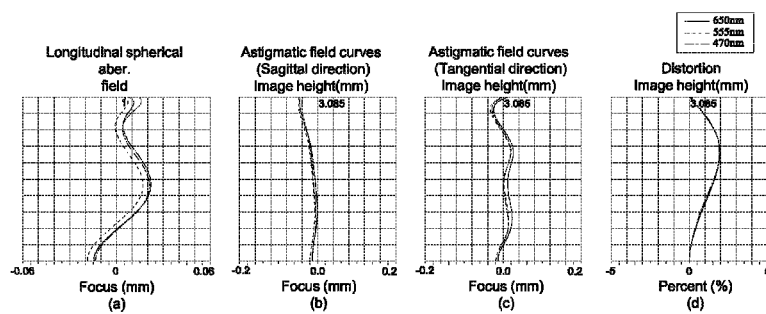


FIG. 3

f(Focus)=3.97 mm, HFOV(Half angular field of view)= 37.68deg., Fno=2.20							
Surface #		Radius	Thickness	Refractive index	Abbe number	Material	Focus
-	Object	$\infty$	$\infty$				
100	Aperture stop	$\infty$	-0.240				
111	1st lens element	1.685	0.643	1.544	56.114	plastic	3.114
112		165.818	0.077				
121	2nd lens element	7.683	0.230	1.640	23.265	plastic	-3.415
122		2.715	0.409				
131	3rd lens element	-7.923	0.580	1.544	56.114	plastic	4.593
132		-1.954	0.254				
141	4th lens element	-0.910	0.494	1.640	23.265	plastic	-6.010
142		-1.442	0.052				
151	5th lens element	1.667	0.842	1.544	56.114	plastic	10.187
152		1.479	0.500				
161	IR cut filter	$\infty$	0.300				
162		$\infty$	0.733				
170	Image plane	$\infty$					

FIG. 4

Aspherical parameters					
Surface #	111	112	121	122	131
K	-3.369E-01	0.000E+00	0.000E-00	-1.948E+00	1.276E+01
a <sub>4</sub>	6.140E-03	-5.300E-03	-1.743E-02	1.434E-02	-7.431E-02
a <sub>6</sub>	9.044E-03	-4.064E-02	-1.773E-02	1.011E-02	-6.878E-03
a <sub>8</sub>	-2.155E-02	2.141E-02	2.224E-02	6.001E-02	5.877E-02
a <sub>10</sub>	2.272E-02	-4.845E-02	-3.668E-02	-1.134E-01	-1.045E-01
a <sub>12</sub>	-2.807E-02	4.502E-03	-3.220E-02	8.133E-02	5.018E-02
a <sub>14</sub>	6.637E-03	-2.586E-03	7.146E-02	1.756E-02	-9.330E-03
a <sub>16</sub>	-6.598E-03	8.882E-03	-1.845E-02	-1.747E-02	1.588E-02
Surface #	132	141	142	151	152
K	-2.937E+01	-6.566E+00	-3.737E+00	-1.413E+01	-5.516E+00
a <sub>4</sub>	-3.625E-01	-3.220E-01	-1.495E-01	-1.463E-01	-7.820E-02
a <sub>6</sub>	4.105E-01	3.018E-01	1.016E-01	4.378E-02	2.376E-02
a <sub>8</sub>	-2.957E-01	-1.730E-02	-1.390E-02	-3.628E-03	-5.498E-03
a <sub>10</sub>	1.503E-01	-6.569E-02	2.373E-03	-4.381E-04	6.715E-04
a <sub>12</sub>	-4.730E-02	-1.567E-02	-2.863E-03	1.030E-04	-1.313E-05
a <sub>14</sub>	-9.062E-03	3.497E-02	7.565E-04	-6.373E-06	-6.900E-06
a <sub>16</sub>	1.079E-02	-9.875E-03	-5.468E-05	1.156E-07	5.824E-07

FIG. 5

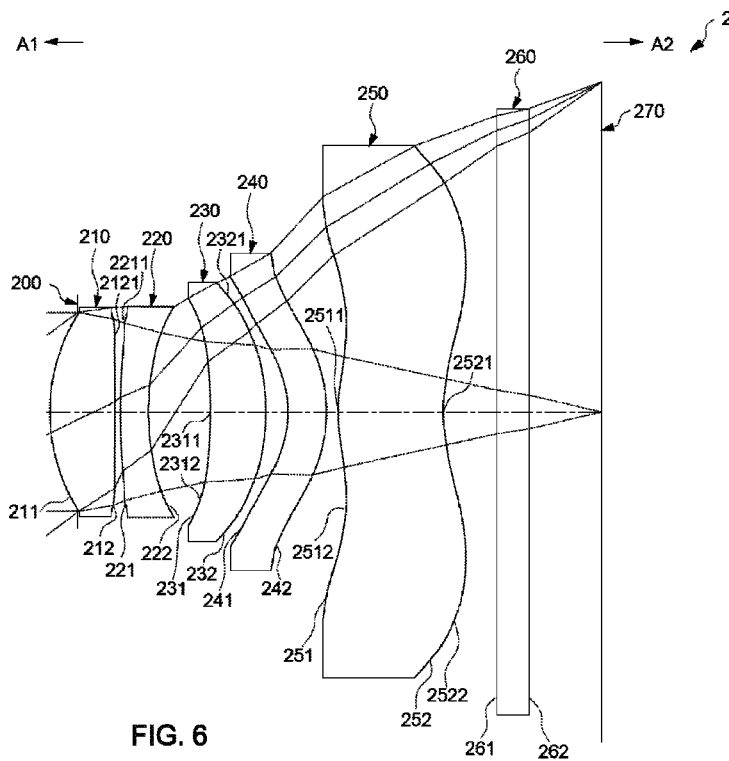


FIG. 6

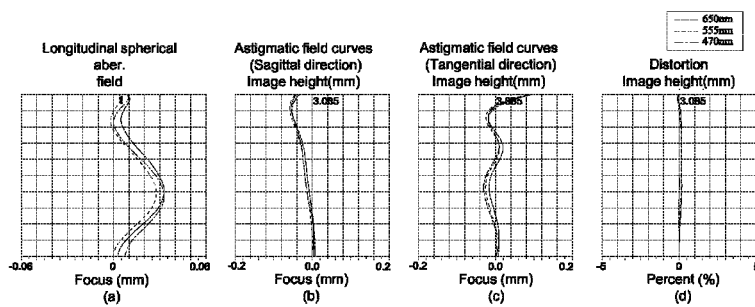


FIG. 7

f(Focus)=4.10mm, HFOV(Half angular field of view)=36.96deg., Fno=2.20							
Surface #		Radius	Thickness	Refractive index	Abbe number	Material	Focus
-	Object	$\infty$	$\infty$				
200	Aperture stop	$\infty$	-0.256				
211	1st lens element	1.737	0.602	1.544	56.114	plastic	3.134
212		-100.310	0.050				
221	2nd lens element	5.501	0.261	1.640	23.265	plastic	-6.539
222		2.342	0.575				
231	3rd lens element	-8.092	0.520	1.544	56.114	plastic	5.278
232		-2.173	0.213				
241	4th lens element	-0.848	0.356	1.640	23.265	plastic	-5.258
242		-1.318	0.106				
251	5th lens element	1.624	0.980	1.544	56.114	plastic	4.447
252		1.533	0.500				
261	IR cut filter	$\infty$	0.300				
262		$\infty$	0.680				
270	Image plane	$\infty$					

FIG. 8

Aspherical parameters					
Surface #	211	212	221	222	231
K	-3.559E-01	0.000E+00	0.000E+00	-2.278E+00	4.019E+01
$a_4$	4.726E-03	9.450E-03	-1.484E-02	1.160E-02	-8.473E-02
$a_6$	9.692E-03	-3.695E-02	-1.190E-02	9.563E-03	-1.464E-02
$a_8$	-2.050E-02	2.391E-02	2.389E-02	6.064E-02	5.791E-02
$a_{10}$	2.434E-02	-4.613E-02	-3.729E-02	-1.134E-01	-1.031E-01
$a_{12}$	-2.642E-02	5.799E-03	-3.369E-02	8.082E-02	5.073E-02
$a_{14}$	7.441E-03	-3.152E-03	6.980E-02	1.682E-02	-9.993E-03
$a_{16}$	-7.633E-03	6.063E-03	-1.987E-02	-1.849E-02	1.455E-02
Surface #	232	241	242	251	252
K	-4.709E+01	-6.767E+00	-3.770E+00	-1.627E+01	-6.170E+00
$a_4$	-3.858E-01	-3.239E-01	-1.468E-01	-1.453E-01	-7.641E-02
$a_6$	4.019E-01	2.987E-01	1.022E-01	4.402E-02	2.364E-02
$a_8$	-2.981E-01	-1.795E-02	-1.367E-02	-3.612E-03	-5.480E-03
$a_{10}$	1.492E-01	-6.511E-02	2.474E-03	-4.381E-04	6.770E-04
$a_{12}$	-4.793E-02	-1.514E-02	-2.844E-03	1.028E-04	-1.259E-05
$a_{14}$	-9.344E-03	3.519E-02	7.541E-04	-6.413E-06	-6.912E-06
$a_{16}$	1.070E-02	-9.917E-03	-5.878E-05	1.174E-07	5.654E-07

FIG. 9

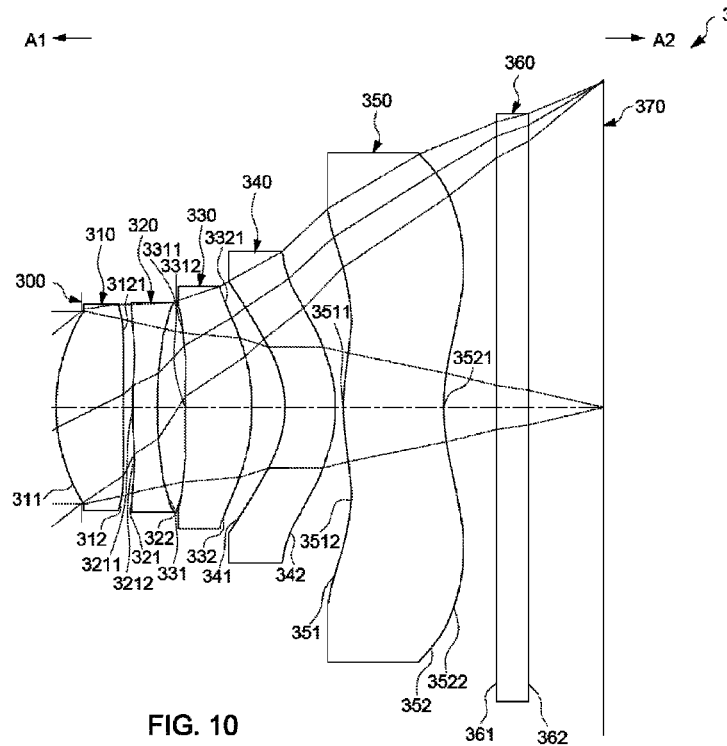


FIG. 10

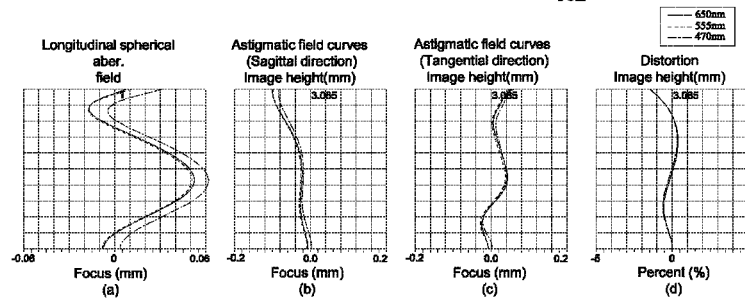


FIG. 11

f(Focus)=4.00mm, HFOV(Half angular field of view)=37.97 deg., Fno=2.20							
Surface #		Radius	Thickness	Refractive index	Abbe number	Material	Focus
-	Object	$\infty$	$\infty$				
300	Aperture stop	$\infty$	-0.240				
311	1st lens element	1.736	0.631	1.544	56.114	plastic	3.163
312		-289.046	0.094				
321	2nd lens element	41.641	0.228	1.640	23.265	plastic	-6.389
322		3.740	0.267				
331	3rd lens element	-15.835	0.617	1.544	56.114	plastic	4.155
332		-2.011	0.320				
341	4th lens element	-0.892	0.469	1.640	23.265	plastic	-5.182
342		-1.467	0.082				
351	5th lens element	1.940	0.939	1.544	56.114	plastic	35.556
352		1.787	0.500				
361	IR cut filter	$\infty$	0.300				
362		$\infty$	0.713				
370	Image plane	$\infty$					

FIG. 12

Aspherical parameters					
Surface #	311	312	321	322	331
K	-3.602E-01	0.000E+00	0.000E+00	-3.502E+00	-9.220E-01
$a_4$	4.550E-03	6.584E-04	-1.597E-02	7.368E-03	-6.379E-02
$a_6$	1.166E-02	-3.779E-02	-8.256E-03	6.906E-04	-1.977E-04
$a_8$	-1.969E-02	2.190E-02	7.548E-03	5.471E-02	6.523E-02
$a_{10}$	2.577E-02	-4.936E-02	-4.335E-02	-1.148E-01	-9.836E-02
$a_{12}$	-2.526E-02	2.522E-03	-2.956E-02	7.655E-02	5.561E-02
$a_{14}$	6.589E-03	-4.780E-03	7.619E-02	1.647E-02	-9.311E-03
$a_{16}$	-1.194E-02	8.040E-03	-1.778E-02	-9.987E-03	1.027E-02
Surface #	332	341	342	351	352
K	-3.536E+01	-5.029E+00	-4.067E-00	-1.415E+01	-5.948E-00
$a_4$	-3.504E-01	-3.324E-01	-1.503E-01	-1.467E-01	-7.743E-02
$a_6$	4.101E-01	2.987E-01	1.023E-01	4.356E-02	2.396E-02
$a_8$	-2.928E-01	-1.744E-02	-1.384E-02	-3.542E-03	-5.498E-03
$a_{10}$	1.510E-01	-6.530E-02	2.376E-03	-4.361E-04	6.728E-04
$a_{12}$	-4.641E-02	-1.587E-02	-2.883E-03	1.004E-04	-1.313E-05
$a_{14}$	-8.242E-03	3.448E-02	7.498E-04	-6.419E-06	-6.896E-06
$a_{16}$	1.144E-02	-9.751E-03	-5.384E-05	1.676E-07	5.734E-07

FIG. 13

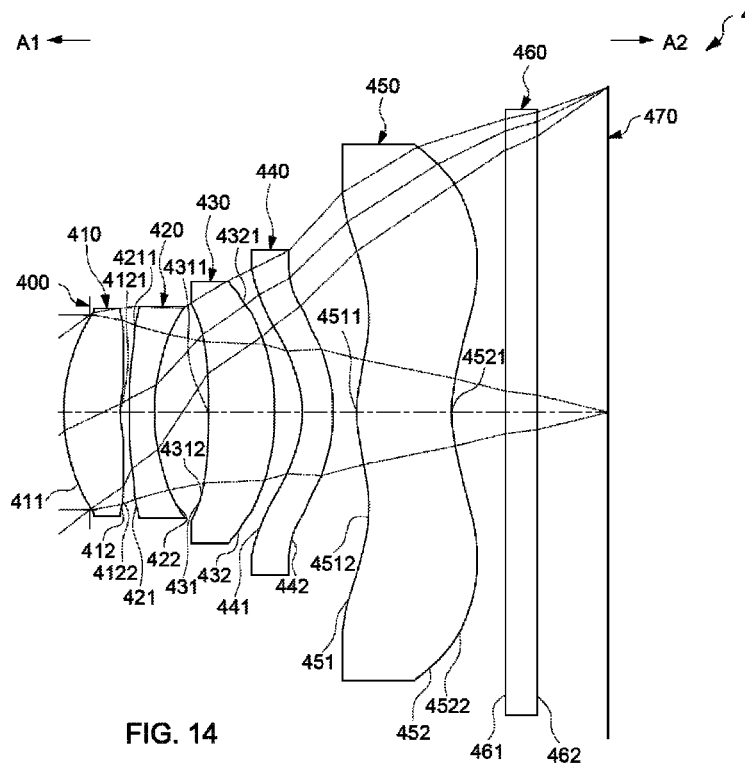


FIG. 14

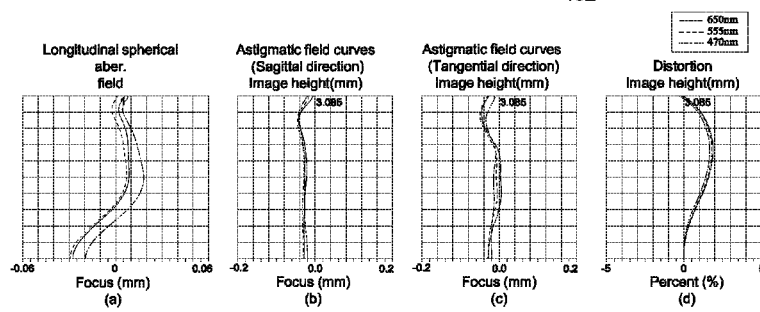


FIG. 15

f(Focus)=4.06mm, HPOV(Half angular field of view)=37.04 deg., Fno=2.20							
Surface #		Radius	Thickness	Refractive index	Abbe number	Material	Focus
-	Object	$\infty$	$\infty$				
400	Aperture stop	$\infty$	-0.240				
411	1st lens element	1.729	0.560	1.544	56.114	plastic	3.212
412		108.994	0.054				
421	2nd lens element	3.396	0.245	1.640	23.265	plastic	-6.183
422		1.782	0.504				
431	3rd lens element	-9.377	0.625	1.544	56.114	plastic	5.411
432		-2.299	0.263				
441	4th lens element	-0.965	0.292	1.640	23.265	plastic	-4.901
442		-1.553	0.230				
451	5th lens element	1.474	0.899	1.544	56.114	plastic	10.594
452		1.553	0.500				
461	IR cut filter	$\infty$	0.300				
462		$\infty$	0.675				
470	Image plane	$\infty$					

FIG. 16

Aspherical parameters					
Surface #	411	412	421	422	431
K	6.994E-01	0.000E+00	0.000E+00	-8.024E+00	3.819E+01
a <sub>4</sub>	-1.643E-02	-6.272E-02	-1.623E-01	7.082E-02	-7.307E-02
a <sub>6</sub>	-4.216E-03	1.463E-01	2.833E-01	-4.882E-02	-3.493E-02
a <sub>8</sub>	-1.980E-02	-1.546E-01	-2.725E-01	2.191E-01	6.401E-02
a <sub>10</sub>	2.072E-02	-1.852E-02	4.744E-02	-3.089E-01	-1.522E-02
a <sub>12</sub>	-4.823E-02	6.873E-02	6.463E-02	7.169E-02	-2.081E-01
a <sub>14</sub>	4.869E-02	5.973E-03	2.301E-02	2.334E-01	2.569E-01
a <sub>16</sub>	-2.991E-02	-3.027E-02	-3.841E-02	-1.443E-01	-7.735E-02
Surface #	432	441	442	451	452
K	-2.132E+01	-5.450E+00	-5.038E+00	-8.933E+00	-4.095E+00
a <sub>4</sub>	-1.817E-01	-1.334E-01	-1.467E-01	-1.370E-01	-9.021E-02
a <sub>6</sub>	8.368E-02	-1.404E-03	8.241E-02	3.294E-02	2.867E-02
a <sub>8</sub>	-1.106E-01	1.514E-01	2.802E-03	-1.395E-03	-6.670E-03
a <sub>10</sub>	2.384E-01	-5.471E-02	2.314E-03	-4.938E-04	7.952E-04
a <sub>12</sub>	-2.901E-01	-4.550E-02	-3.346E-03	9.930E-05	-4.413E-06
a <sub>14</sub>	1.688E-01	3.794E-02	-2.524E-04	-1.095E-05	-9.715E-06
a <sub>16</sub>	-3.702E-02	-8.305E-03	2.225E-04	6.333E-07	7.210E-07

FIG. 17

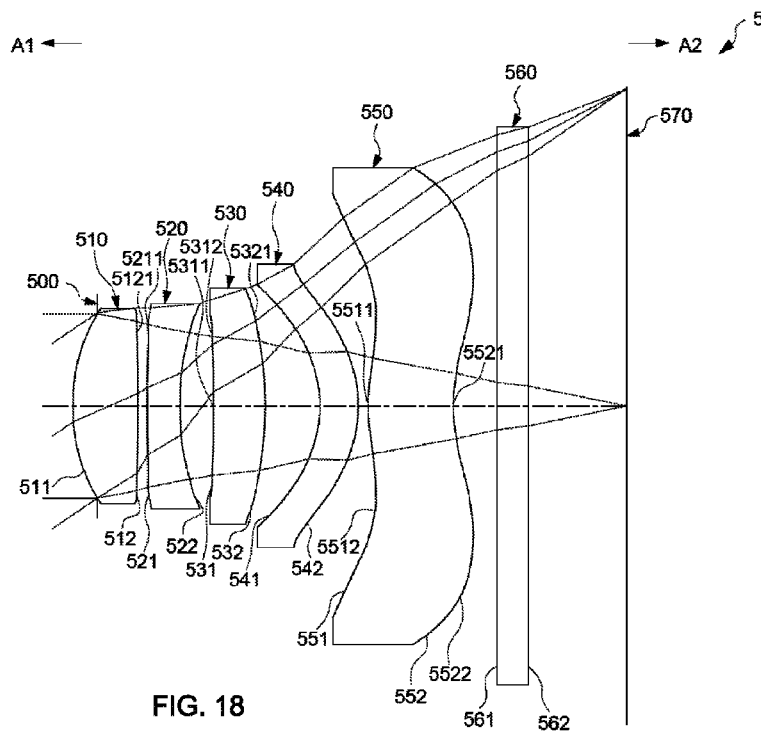


FIG. 18

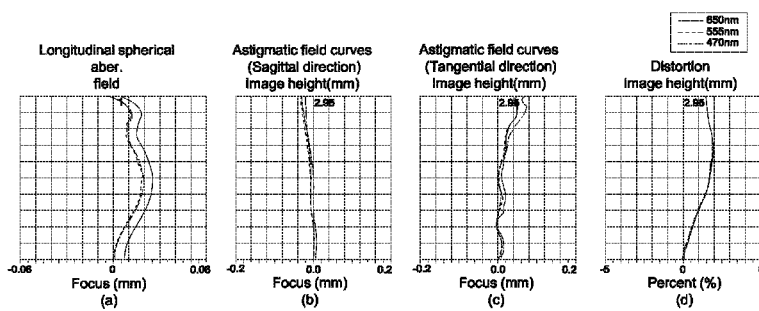


FIG. 19

f(Focus)=4.30mm, HFOV(Half angular field of view)=34.00 deg., Fno=2.50							
Surface #		Radius	Thickness	Refractive index	Abbe number	Material	Focus
-	Object	$\infty$	$\infty$				
500	Aperture stop	$\infty$	-0.224				
511	1st lens element	1.733	0.601	1.546	56.114	plastic	2.940
512		-19.055	0.090				
521	2nd lens element	11.153	0.300	1.637	23.413	plastic	-4.985
522		2.446	0.315				
531	3rd lens element	-14.732	0.479	1.533	55.731	plastic	8.540
532		-3.516	0.508				
541	4th lens element	-0.976	0.350	1.586	30.181	plastic	-12.026
542		-1.283	0.100				
551	5th lens element	1.732	0.790	1.533	55.731	plastic	71.727
552		1.526	0.400				
561	IR cut filter	$\infty$	0.300				
562		$\infty$	0.889				
570	Image plane	$\infty$	0.012				

FIG. 20

Aspherical parameters				
Surface #	511	512	521	522
K	1.733E+00	-1.906E+01	1.115E+01	2.446E+00
$a_4$	1.522E+00	0.000E+00	0.000E+00	-1.632E+01
$a_6$	-3.871E-02	2.891E-02	-1.273E-02	1.312E-01
$a_8$	-1.215E-02	-4.911E-02	-1.264E-02	-1.976E-01
$a_{10}$	-4.560E-02	-3.579E-03	-8.169E-02	2.442E-01
$a_{12}$	4.439E-02	9.398E-02	1.944E-01	-1.722E-01
$a_{14}$	-4.520E-02	-6.623E-02	-9.785E-02	6.177E-02
Surface #	541	542	551	552
K	-7.415E+00	-1.046E+01	-2.762E+00	-3.965E+00
$a_4$	-3.602E-01	-4.322E-01	-3.399E-01	-1.346E-01
$a_6$	4.309E-01	4.525E-01	2.048E-01	5.416E-02
$a_8$	-5.115E-01	-3.447E-01	-7.815E-02	-1.498E-02
$a_{10}$	3.591E-01	1.652E-01	1.628E-02	2.196E-03
$a_{12}$	-1.016E-01	-2.984E-02	-1.339E-03	-1.412E-04

FIG. 21

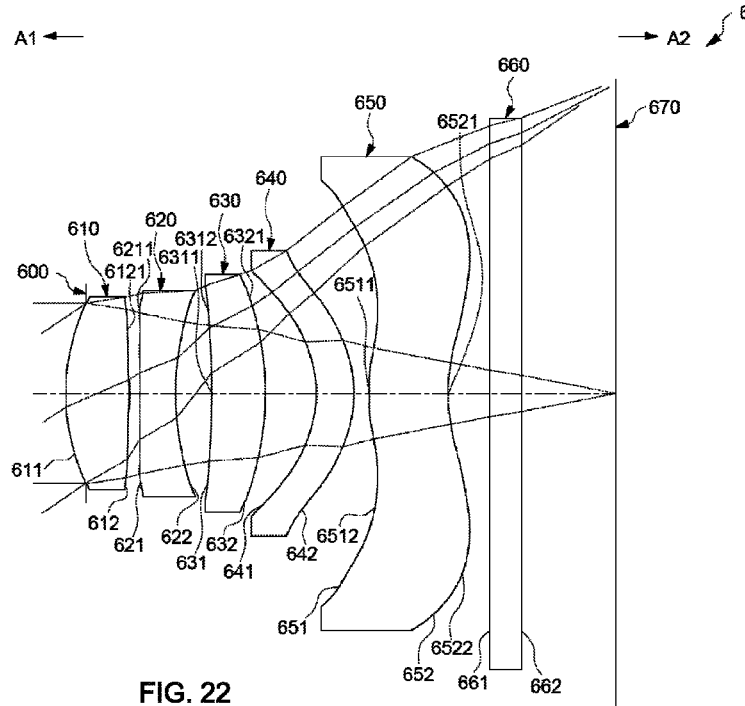


FIG. 22

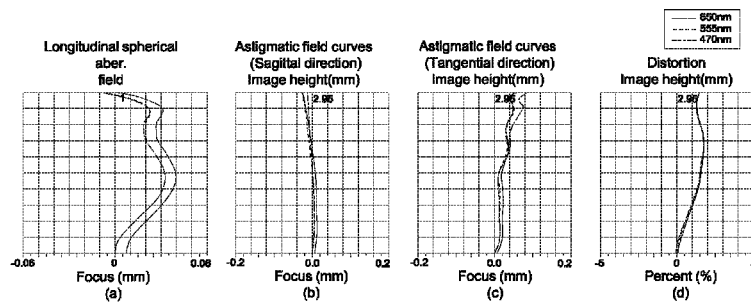


FIG. 23

f(Focus)=4.30mm, HFOV(Half angular field of view)=33.96 deg., Fno=2.50							
Surface #		Radius	Thickness	Refractive index	Abbe number	Material	Focus
-	Object	$\infty$	$\infty$				
600	Aperture stop	$\infty$	-0.198				
611	1st lens element	1.900	0.602	1.546	56.114	plastic	2.985
612		-10.160	0.098				
621	2nd lens element	13.885	0.345	1.637	23.413	plastic	-5.017
622		2.573	0.344				
631	3rd lens element	-8.602	0.503	1.546	56.114	plastic	7.677
632		-2.876	0.491				
641	4th lens element	-1.023	0.350	1.586	30.181	plastic	-17.371
642		-1.281	0.150				
651	5th lens element	1.766	0.744	1.533	55.731	plastic	-45.576
652		1.405	0.400				
661	IR cut filter	$\infty$	0.300				
662		$\infty$	0.877				
670	Image plane	$\infty$	0.023				

FIG. 24

Aspherical parameters				
Surface #	611	612	621	622
K	1.743E+00	0.000E+00	0.000E+00	-1.801E+01
$a_4$	-3.936E-02	2.556E-02	-1.061E-02	1.242E-01
$a_6$	-7.990E-03	-6.485E-02	-8.748E-03	-1.974E-01
$a_8$	-4.720E-02	1.301E-02	-8.251E-02	2.496E-01
$a_{10}$	2.699E-02	8.134E-02	1.937E-01	-1.859E-01
$a_{12}$	-1.758E-02	-5.640E-02	-9.147E-02	6.653E-02
Surface #	641	642	651	652
K	-7.018E+00	-9.172E+00	-2.263E+00	-4.233E+00
$a_4$	-3.647E-01	-4.232E-01	-3.376E-01	-1.291E-01
$a_6$	4.373E-01	4.514E-01	2.049E-01	5.368E-02
$a_8$	-5.115E-01	-3.461E-01	-7.842E-02	-1.498E-02
$a_{10}$	3.573E-01	1.644E-01	1.619E-02	2.163E-03
$a_{12}$	-1.002E-01	-3.008E-02	-1.347E-03	-1.338E-04

FIG. 25

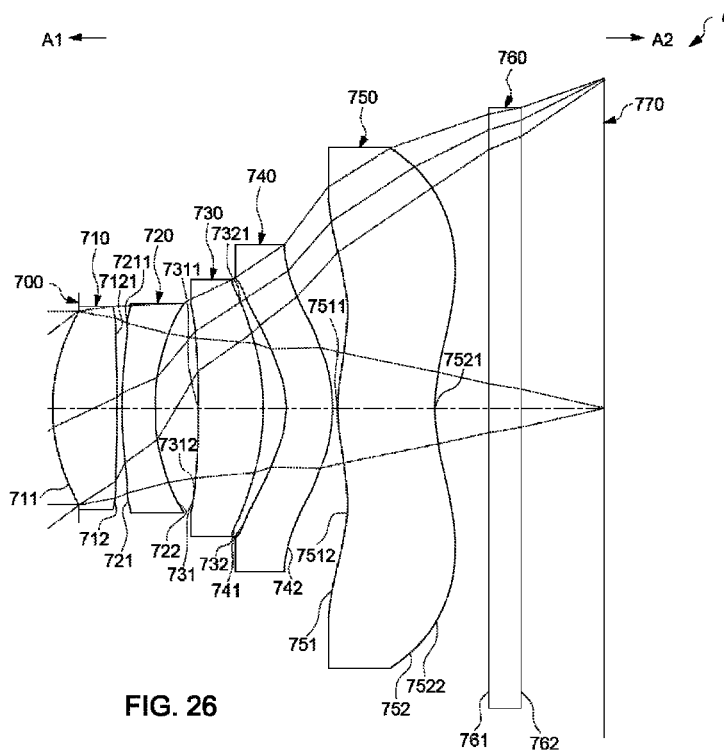


FIG. 26

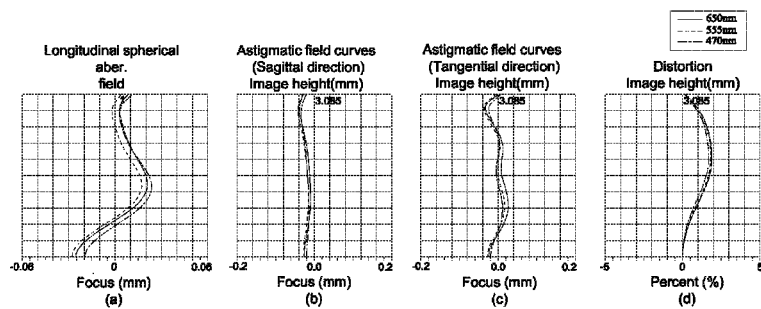


FIG. 27

f(Focus)=4.00mm, HFOV(Half angular field of view)=37.39 deg., Fno=2.20							
Surface #		Radius	Thickness	Refractive index	Abbe number	Material	Focus
-	Object	$\infty$					
700	Aperture stop	$\infty$	-0.240				
711	1st lens element	1.758	0.597	1.544	56.114	plastic	3.200
712		-247.429	0.049				
721	2nd lens element	3.806	0.312	1.640	23.265	plastic	-6.335
722		1.907	0.400				
731	3rd lens element	-18.450	0.604	1.544	56.114	plastic	5.210
732		-2.493	0.218				
741	4th lens element	-0.915	0.431	1.640	23.265	plastic	-4.669
742		-1.557	0.051				
751	5th lens element	1.538	0.910	1.544	56.114	plastic	9.267
752		1.749	0.500				
761	IR cut filter	$\infty$	0.300				
762		$\infty$	0.778				
770	Image plane	$\infty$					

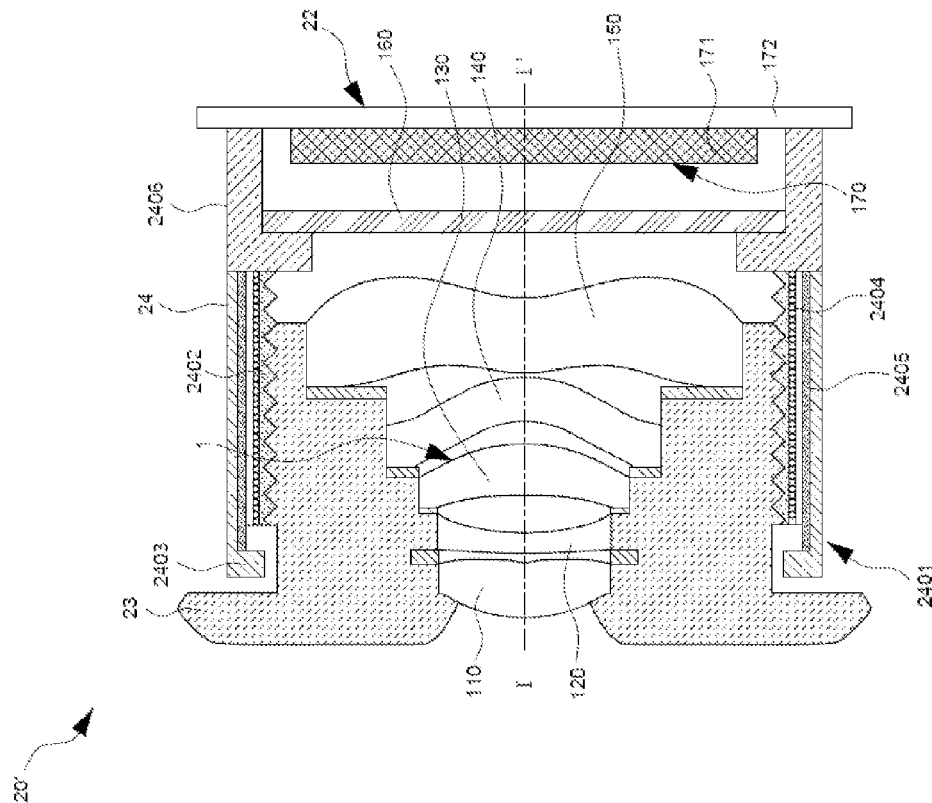
FIG. 28

Aspherical parameters					
Surface #	711	712	721	722	731
K	-3.569E-01	-5.156E+01	0.000E+00	-2.782E+00	9.476E+00
$a_4$	3.262E-03	-1.062E-02	-5.453E-02	8.583E-03	-6.396E-02
$a_6$	1.763E-02	-3.340E-03	4.145E-02	2.192E-02	2.386E-02
$a_8$	-3.706E-02	3.516E-03	-2.550E-02	6.885E-02	1.816E-02
$a_{10}$	2.247E-02	-7.187E-02	-3.030E-02	-1.375E-01	-8.486E-02
$a_{12}$	-1.692E-02	2.896E-02	-1.258E-02	8.318E-02	7.298E-02
$a_{14}$	1.736E-02	3.249E-02	6.742E-02	3.715E-02	-1.269E-02
$a_{16}$	-1.914E-02	-2.941E-02	-3.455E-02	-3.621E-02	5.609E-03
Surface #	732	741	742	751	752
K	-6.143E+01	-7.311E+00	-3.552E+00	-1.349E+01	-5.315E+00
$a_4$	-3.075E-01	-2.843E-01	-1.344E-01	-1.389E-01	-8.200E-02
$a_6$	3.882E-01	2.972E-01	1.087E-01	4.256E-02	2.384E-02
$a_8$	-2.991E-01	-2.695E-02	-1.537E-02	-3.606E-03	-5.425E-03
$a_{10}$	1.464E-01	-7.489E-02	1.172E-03	-4.302E-04	6.734E-04
$a_{12}$	-4.570E-02	-1.467E-02	-2.929E-03	1.011E-04	-1.604E-05
$a_{14}$	-6.802E-03	4.180E-02	8.730E-04	-6.731E-06	-7.243E-06
$a_{16}$	9.913E-03	-1.231E-02	-6.538E-05	2.028E-07	6.549E-07

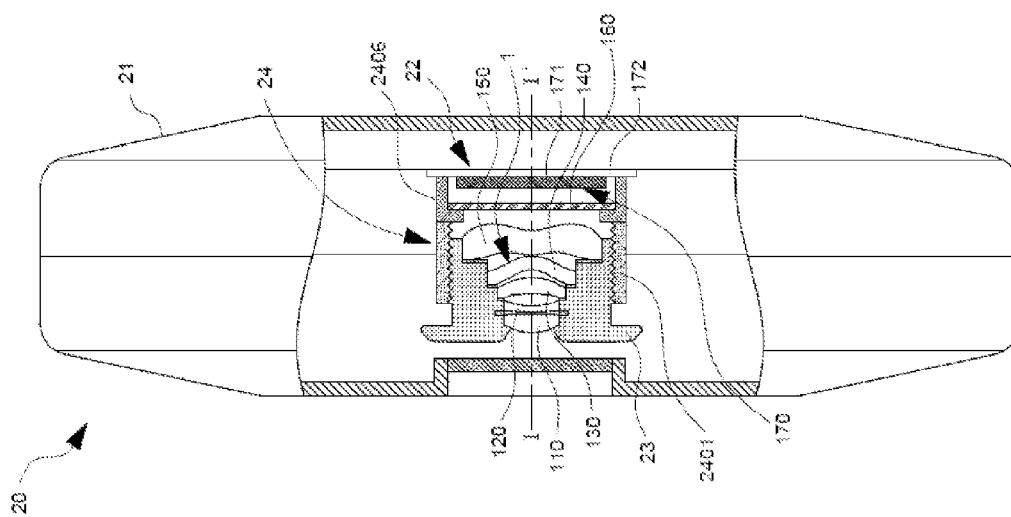
FIG. 29

Embodiment	1 <sup>st</sup> Embodiment	2 <sup>nd</sup> Embodiment	3 <sup>rd</sup> Embodiment	4 <sup>th</sup> Embodiment	5 <sup>th</sup> Embodiment	6 <sup>th</sup> Embodiment	7 <sup>th</sup> Embodiment
T2	0.23	0.26	0.23	0.24	0.30	0.35	0.31
T4	0.49	0.36	0.47	0.29	0.35	0.35	0.43
T5	0.84	0.98	0.94	0.90	0.79	0.74	0.91
G23	0.41	0.58	0.27	0.50	0.32	0.34	0.40
G34	0.25	0.21	0.32	0.26	0.51	0.49	0.22
Gaa	0.79	0.94	0.76	1.05	1.01	1.08	0.72
CTmin	0.23	0.26	0.23	0.24	0.30	0.35	0.31
CTmax	0.84	0.98	0.94	0.90	0.79	0.74	0.91
Dmax	0.84	0.98	0.94	0.90	0.79	0.74	0.91
BFL	1.53	1.48	1.51	1.48	1.60	1.60	1.58
ALT	2.79	2.72	2.88	2.62	2.52	2.54	2.85
EFL	3.97	4.10	4.00	4.06	4.30	4.30	4.00
Gaa/T4	1.60	2.65	1.63	3.60	2.90	3.09	1.67
Gaa/T2	3.44	3.62	3.35	4.29	3.38	3.14	2.30
EFL/G23	9.70	7.13	14.99	8.06	13.64	12.49	9.99
EFL/DMAX	4.71	4.18	4.26	4.52	5.44	5.78	4.40
T5/CTMIN	3.65	3.75	4.13	3.67	2.63	2.15	2.92
Gaa/G34	3.11	4.44	2.38	3.99	1.99	2.21	3.30
CTMAX/CTMIN	3.65	3.75	4.13	3.67	2.63	2.15	2.92
EFL/T5	4.71	4.18	4.26	4.52	5.44	5.78	4.40
Gaa/G23	1.94	1.64	2.86	2.09	3.21	3.15	1.79
IV2-V4I	0.00	0.00	0.00	0.00	6.77	6.77	0.00
G23/CTMIN	1.78	2.20	1.17	2.06	1.05	1.00	1.28
ALT/CTMIN	12.10	10.42	12.67	10.71	8.40	7.37	9.15
BFL/G23	3.75	2.57	5.67	2.93	5.08	4.65	3.94
ALT/Gaa	3.52	2.88	3.78	2.50	2.49	2.35	3.97
DMAX/CTMIN	3.65	3.75	4.13	3.67	2.63	2.15	2.92
ALT/T2	12.10	10.42	12.67	10.71	8.40	7.37	9.15
ALT/G34	10.97	12.78	9.01	9.96	4.96	5.19	13.11

FIG. 30



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# MOBILE DEVICE AND OPTICAL IMAGING LENS THEREOF

## INCORPORATION BY REFERENCE

This application claims priority from P.R.C. Patent Application No. 201310297153.2, filed on Jul. 16, 2013, the contents of which are hereby incorporated by reference in their entirety for all purposes.

## TECHNICAL FIELD

The present invention relates to a mobile device and an optical imaging lens thereof, and particularly, relates to a mobile device applying an optical imaging lens having five lens elements and an optical imaging lens thereof.

## BACKGROUND

The ever-increasing demand for smaller sized mobile devices, such as cell phones, digital cameras, etc. correspondingly triggered a growing need for a smaller sized photography module, comprising elements such as an optical imaging lens, a module housing unit, and an image sensor, etc., contained therein. Size reductions may be contributed from various aspects of the mobile devices, which includes not only the charge coupled device (CCD) and the complementary metal-oxide semiconductor (CMOS), but also the optical imaging lens mounted therein. When reducing the size of the optical imaging lens, however, achieving good optical characteristics becomes a challenging problem.

U.S. Patent Publication No. 20100253829, 20110316969 and 20100254029, U.S. Pat. No. 7,480,105 and Japan Patent Publication No. 2010-026434 and 2010-008562 all disclosed an optical imaging lens constructed with an optical imaging lens having five lens elements, wherein the length of the optical imaging lens, from the object-side surface of the first lens element to the image plane, are too long for smaller sized mobile devices. Therefore, there is needed to develop optical imaging lens which is capable to place with five lens elements therein, with a shorter length, while also having good optical characters.

## SUMMARY

An object of the present invention is to provide a mobile device and an optical imaging lens thereof. With controlling the convex or concave shape of the surfaces and/or the refracting power of the lens elements, the length of the optical imaging lens is shortened and meanwhile the good optical characters, and system functionality are sustained.

In an exemplary embodiment, an optical imaging lens comprises, sequentially from an object side to an image side along an optical axis, comprises an aperture stop, first, second, third, fourth and fifth lens elements, each of the first, second, third, fourth and fifth lens elements having an object-side surface facing toward the object side and an image-side surface facing toward the image side, wherein: the first lens element has positive refracting power, and the image-side surface thereof comprises a convex portion in a vicinity of a periphery of the first lens element; the second lens element has negative refracting power, and the image-side surface thereof is a concave surface; the object-side surface of the third lens element comprises a concave portion in a vicinity of a periphery of the third lens element, and the image-side surface of the third lens element com-

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prises a convex portion in a vicinity of a periphery of the third lens element; the object-side surface of the fourth lens element is a concave surface; the image-side surface of the fifth lens element comprises a concave portion in a vicinity of the optical axis and a convex portion in a vicinity of a periphery of the fifth lens element; a central thickness of the third lens element along the optical axis is thicker than a central thickness of the fourth lens element along the optical axis; and the optical imaging lens as a whole comprises only the five lens elements having refracting power.

In another exemplary embodiment, other equation (s), such as those relating to the ratio among parameters could be taken into consideration. For example, a central thickness of the fourth lens element along the optical axis, T4, and the sum of all four air gaps from the first lens element to the fifth lens element along the optical axis, Gaa, could be controlled to satisfy the equation as follows:

$$1.6 \leq Gaa/T4 \leq 3.6 \quad \text{Equation (1); or}$$

Gaa and a central thickness of the second lens element along the optical axis, T2, could be controlled to satisfy the equation (s) as follows:

$$2.3 \leq Gaa/T2 \leq 4.3 \quad \text{Equation (2); or}$$

An air gap between the second lens element and the third lens element along the optical axis, G23, and an effective focal length, EFL, could be controlled to satisfy the equation (s) as follows:

$$7 \leq EFL/G23 \leq 16 \quad \text{Equation (3); or}$$

EFL and the maximum of the nine values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements on the optical axis and the four air gaps between any two adjacent lens elements of the first, second, third, fourth and fifth lens elements on the optical axis, Dmax, could be controlled to satisfy the equation as follows:

$$EFL/Dmax \leq 5.5 \quad \text{Equation (4); or}$$

A central thickness of the fifth lens element along the optical axis, T5, and the minimum of the five values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements along the optical axis, CTmin, could be controlled to satisfy the equation as follows:

$$2.6 \leq T5/CTmin \quad \text{Equation (5); or}$$

Gaa and an air gap between the third lens element and the fourth lens element along the optical axis, G34, could be controlled to satisfy the equation as follows:

$$Gaa/G34 \leq 3.75 \quad \text{Equation (6); or}$$

CTmin and the maximum of the five values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements along the optical axis, CTmax, could be controlled to satisfy the equation as follows:

$$CTmax/CTmin \leq 3.1 \quad \text{Equation (7); or}$$

T5 and EFL could be controlled to satisfy the equation as follows:

$$EFL/T5 \leq 6.0 \quad \text{Equation (8); or}$$

G23 and Gaa could be controlled to satisfy the equation as follows:

$$Gaa/G23 \leq 2.6 \quad \text{Equation (9); or}$$

The abbe number of the second lens element, V2, and the abbe number of the fourth lens element, V4, could be controlled to satisfy the equation as follows:

$$0 \leq |V2 - V4| \leq 10 \quad \text{Equation (10); or}$$

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G23 and CTmin could be controlled to satisfy the equation as follows:

$$G23/CTmin \leq 1.6 \quad \text{Equation (11); or}$$

CTmin and the sum of the thickness of all five lens elements along the optical axis, ALT, could be controlled to satisfy the equation as follows:

$$ALT/CTmin \leq 9.5 \quad \text{Equation (12); or}$$

G23 and a back focal length of the optical imaging lens, i.e. the distance from the image-side surface of the fifth lens element to an image plane on the optical axis, BFL, could be controlled to satisfy the equation as follows:

$$3.9 \leq BFL/G23 \quad \text{Equation (13); or}$$

ALT and Gaa could be controlled to satisfy the equation as follows:

$$2.3 \leq ALT/Gaa \leq 3.6 \quad \text{Equation (14); or}$$

Dmax and Dmin could be controlled to satisfy the equation as follows:

$$2.6 \leq Dmax/CTmin \quad \text{Equation (15); or}$$

ALT and T2 could be controlled to satisfy the equation as follows:

$$ALT/T2 \leq 9.5 \quad \text{Equation (16); or}$$

ALT and G34 could be controlled to satisfy the equation as follows:

$$3.5 \leq ALT/G34 \leq 15 \quad \text{Equation (17).}$$

Aforesaid exemplary embodiments are not limited and could be selectively incorporated in other embodiments described herein.

In some exemplary embodiments, more details about the convex or concave surface structure could be incorporated for one specific lens element or broadly for plural lens elements to enhance the control for the system performance and/or resolution. For example, the object-side surface of the third lens element comprises a concave portion in a vicinity of the optical axis, the image-side surface of the first lens element may comprise a convex portion in a vicinity of the optical axis, and/or the object-side surface of the second lens element comprises a convex portion in a vicinity of a periphery of the second lens element, etc. It is noted that the details listed here could be incorporated in example embodiments if no inconsistency occurs.

In another exemplary embodiment, a mobile device comprising a housing and a photography module positioned in the housing is provided. The photography module comprises any of aforesaid example embodiments of optical imaging lens, a lens barrel, a module housing unit and an image sensor. The lens barrel is for positioning the optical imaging lens, the module housing unit is for positioning the lens barrel, the substrate is for positioning the module housing unit; and the image sensor is positioned at the image side of the optical imaging lens.

Through controlling the convex or concave shape of the surfaces and/or the refraction power of the lens element(s), the mobile device and the optical imaging lens thereof in exemplary embodiments achieve good optical characters and effectively shorten the length of the optical imaging lens.

## BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments will be more readily understood from the following detailed description when read in conjunction with the appended drawing, in which:

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FIG. 1 is a cross-sectional view of one single lens element according to the present disclosure;

FIG. 2 is a cross-sectional view of a first embodiment of an optical imaging lens having five lens elements according to the present disclosure;

FIG. 3 is a chart of longitudinal spherical aberration and other kinds of optical aberrations of a first embodiment of the optical imaging lens according to the present disclosure;

FIG. 4 is a table of optical data for each lens element of a first embodiment of an optical imaging lens according to the present disclosure;

FIG. 5 is a table of aspherical data of a first embodiment of the optical imaging lens according to the present disclosure;

FIG. 6 is a cross-sectional view of a second embodiment of an optical imaging lens having five lens elements according to the present disclosure;

FIG. 7 is a chart of longitudinal spherical aberration and other kinds of optical aberrations of a second embodiment of the optical imaging lens according to the present disclosure;

FIG. 8 is a table of optical data for each lens element of the optical imaging lens of a second embodiment of the present disclosure;

FIG. 9 is a table of aspherical data of a second embodiment of the optical imaging lens according to the present disclosure;

FIG. 10 is a cross-sectional view of a third embodiment of an optical imaging lens having five lens elements according to the present disclosure;

FIG. 11 is a chart of longitudinal spherical aberration and other kinds of optical aberrations of a third embodiment of the optical imaging lens according to the present disclosure;

FIG. 12 is a table of optical data for each lens element of the optical imaging lens of a third embodiment of the present disclosure;

FIG. 13 is a table of aspherical data of a third embodiment of the optical imaging lens according to the present disclosure;

FIG. 14 is a cross-sectional view of a fourth embodiment of an optical imaging lens having five lens elements according to the present disclosure;

FIG. 15 is a chart of longitudinal spherical aberration and other kinds of optical aberrations of a fourth embodiment of the optical imaging lens according to the present disclosure;

FIG. 16 is a table of optical data for each lens element of the optical imaging lens of a fourth embodiment of the present disclosure;

FIG. 17 is a table of aspherical data of a fourth embodiment of the optical imaging lens according to the present disclosure;

FIG. 18 is a cross-sectional view of a fifth embodiment of an optical imaging lens having five lens elements according to the present disclosure;

FIG. 19 is a chart of longitudinal spherical aberration and other kinds of optical aberrations of a fifth embodiment of the optical imaging lens according to the present disclosure;

FIG. 20 is a table of optical data for each lens element of the optical imaging lens of a fifth embodiment of the present disclosure;

FIG. 21 is a table of aspherical data of a fifth embodiment of the optical imaging lens according to the present disclosure;

FIG. 22 is a cross-sectional view of a sixth embodiment of an optical imaging lens having five lens elements according to the present disclosure;

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FIG. 23 is a chart of longitudinal spherical aberration and other kinds of optical aberrations of a sixth embodiment of the optical imaging lens according to the present disclosure;

FIG. 24 is a table of optical data for each lens element of the optical imaging lens of a sixth embodiment of the present disclosure;

FIG. 25 is a table of aspherical data of a sixth embodiment of the optical imaging lens according to the present disclosure;

FIG. 26 is a cross-sectional view of a seventh embodiment of an optical imaging lens having five lens elements according to the present disclosure;

FIG. 27 is a chart of longitudinal spherical aberration and other kinds of optical aberrations of a seventh embodiment of the optical imaging lens according to the present disclosure;

FIG. 28 is a table of optical data for each lens element of the optical imaging lens of a seventh embodiment of the present disclosure;

FIG. 29 is a table of aspherical data of a seventh embodiment of the optical imaging lens according to the present disclosure;

FIG. 30 is a table for the values of T2, T4, T5, G23, G34, Gaa, CTmin, CTmax, Dmax, BFL, ALT, EFL, Gaa/T4, Gaa/T2, EFL/G23, EFL/Dmax, T5/CTmin, Gaa/G34, CTmax/CTmin, EFL/T5, Gaa/G23, |V2-V4|, G23/CTmin, ALT/CTmin, BFL/G23, ALT/Gaa, Dmax/CTmin, ALT/T2 and ALT/G34 of all seventh example embodiments;

FIG. 31 is a structure of an example embodiment of a mobile device;

FIG. 32 is a partially enlarged view of the structure of another example embodiment of a mobile device.

#### DETAILED DESCRIPTION

For a more complete understanding of the present disclosure and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which like reference numbers indicate like features. Persons having ordinary skill in the art will understand other varieties for implementing example embodiments, including those described herein. The drawings are not limited to specific scale and similar reference numbers are used for representing similar elements. As used in the disclosures and the appended claims, the terms “example embodiment,” “exemplary embodiment,” and “present embodiment” do not necessarily refer to a single embodiment, although it may, and various example embodiments may be readily combined and interchanged, without departing from the scope or spirit of the present invention. Furthermore, the terminology as used herein is for the purpose of describing example embodiments only and is not intended to be a limitation of the invention. In this respect, as used herein, the term “in” may include “in” and “on”, and the terms “a”, “an” and “the” may include singular and plural references. Furthermore, as used herein, the term “by” may also mean “from”, depending on the context. Furthermore, as used herein, the term “if” may also mean “when” or “upon”, depending on the context. Furthermore, as used herein, the words “and/or” may refer to and encompass any and all possible combinations of one or more of the associated listed items.

Here in the present specification, “a lens element having positive refracting power (or negative refracting power)” means that the lens element has positive refracting power (or negative refracting power) in the vicinity of the optical axis. “An object-side (or image-side) surface of a lens element comprises a convex (or concave) portion in a specific

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region” means that the object-side (or image-side) surface of the lens element “protrudes outwardly (or depresses inwardly)” along the direction parallel to the optical axis at the specific region, compared with the outer region radially adjacent to the specific region. Taking FIG. 1 for example, the lens element shown therein is radially symmetric around the optical axis which is labeled by I. The object-side surface of the lens element comprises a convex portion at region A, a concave portion at region B, and another convex portion at region C. This is because compared with the outer region radially adjacent to the region A (i.e. region B), the object-side surface protrudes outwardly at the region A, compared with the region C, the object-side surface depresses inwardly at the region B, and compared with the region E, the object-side surface protrudes outwardly at the region C. Here, “in a vicinity of a periphery of a lens element” means that in a vicinity of the peripheral region of a surface for passing imaging light on the lens element, i.e. the region C as shown in FIG. 1. The imaging light comprises chief ray Lc and marginal ray Lm. “In a vicinity of the optical axis” means that in a vicinity of the optical axis of a surface for passing the imaging light on the lens element, i.e. the region A as shown in FIG. 1. Further, a lens element could comprise an extending portion E for mounting the lens element in an optical imaging lens. Ideally, the imaging light would not pass the extending portion E. Here the extending portion E is only for example, the structure and shape thereof are not limited to this specific example. Please also noted that the extending portion of all the lens elements in the example embodiments shown below are skipped for maintaining the drawings clean and concise.

Example embodiments of an optical imaging lens may comprise an aperture stop, a first lens element, a second lens element, a third lens element, a fourth lens element and a fifth lens element, each of the lens elements comprises an object-side surface facing toward an object side and an image-side surface facing toward an image side. These lens elements may be arranged sequentially from the object side to the image side along an optical axis, and example embodiments of the lens as a whole may comprise only the five lens elements having refracting power. In an example embodiment: the first lens element has positive refracting power, and the image-side surface thereof comprises a convex portion in a vicinity of a periphery of the first lens element; the second lens element has negative refracting power, and the image-side surface thereof is a concave surface; the object-side surface of the third lens element comprises a concave portion in a vicinity of a periphery of the third lens element, and the image-side surface of the third lens element comprises a convex portion in a vicinity of a periphery of the third lens element; the object-side surface of the fourth lens element is a concave surface; the image-side surface of the fifth lens element comprises a concave portion in a vicinity of the optical axis and a convex portion in a vicinity of a periphery of the fifth lens element; a central thickness of the third lens element along the optical axis is thicker than a central thickness of the fourth lens element along the optical axis.

Preferably, the lens elements are designed in light of the optical characteristics and the length of the optical imaging lens. For example, the first lens element having positive refracting power with the convex portion formed in a vicinity of a periphery of the first lens element on the image-side surface thereof can assist in increasing light converge ability of the optical imaging lens, and combining with the aperture stop positioned before the first lens element, the length of the optical imaging lens can be effec-

tively shortened. Combining the positive refracting power of the first lens element with the negative refracting power of the second lens element, the aberration of the optical imaging lens could be further adjusted. The details of shape on the surfaces of the lens elements listed here, such as the concave surface of the image-side surface of the second lens element, the concave portion a vicinity of a periphery of the third lens element on the image-side surface thereof and the concave surface of the object-side surface of the fourth lens element, could assist in eliminating the aberration of the optical imaging lens. The concave portion in a vicinity of the optical axis on the image-side surface of the fifth lens element and the convex portion in a vicinity of a periphery of the fifth lens element on the image-side surface thereof facilitate the suppression of the incident angle of the light onto the image sensor to adjust high-level aberration of the optical imaging lens. Further, the thicker third lens element and thinner fourth lens element may easily perform as a convex lens and a following concave lens which have better performance on eliminating chromatic aberration or flare to promote the image quality. Additionally, the image quality of the whole system can be promoted even more with additional features, such as the concave portion in a vicinity of the optical axis on the object-side surface of the third lens element, the convex portion in a vicinity of the optical axis on the image-side surface of the first lens element and/or the convex portion in a vicinity of a periphery of the second lens element on the object-side surface thereof.

In another exemplary embodiment, some equation (s) of parameters, such as those relating to the ratio among parameters could be taken into consideration. For example, a central thickness of the fourth lens element along the optical axis, T4, and the sum of all four air gaps from the first lens element to the fifth lens element along the optical axis, Gaa, could be controlled to satisfy the equation as follows:

$$1.6 \leq Gaa/T4 \leq 3.6 \quad \text{Equation (1); or}$$

Gaa and a central thickness of the second lens element along the optical axis, T2, could be controlled to satisfy the equation (s) as follows:

$$2.3 \leq Gaa/T2 \leq 4.3 \quad \text{Equation (2); or}$$

An air gap between the second lens element and the third lens element along the optical axis, G23, and an effective focal length, EFL, could be controlled to satisfy the equation (s) as follows:

$$7 \leq EFL/G23 \leq 16 \quad \text{Equation (3); or}$$

EFL and the maximum of the nine values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements on the optical axis and the four air gaps between any two adjacent lens elements of the first, second, third, fourth and fifth lens elements on the optical axis, Dmax, could be controlled to satisfy the equation as follows:

$$EFL/Dmax \leq 5.5 \quad \text{Equation (4); or}$$

A central thickness of the fifth lens element along the optical axis, T5, and the minimum of the five values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements along the optical axis, CTmin, could be controlled to satisfy the equation as follows:

$$2.6 \leq T5/CTmin \quad \text{Equation (5); or}$$

Gaa and an air gap between the third lens element and the fourth lens element along the optical axis, G34, could be controlled to satisfy the equation as follows:

$$Gaa/G34 \leq 3.75 \quad \text{Equation (6); or}$$

CTmin and the maximum of the five values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements along the optical axis, CTmax, could be controlled to satisfy the equation as follows:

$$CTmax/CTmin \leq 3.1 \quad \text{Equation (7); or}$$

T5 and EFL could be controlled to satisfy the equation as follows:

$$EFL/T5 \leq 6.0 \quad \text{Equation (8); or}$$

G23 and Gaa could be controlled to satisfy the equation as follows:

$$Gaa/G \leq 2.6 \quad \text{Equation (9); or}$$

The abbe number of the second lens element, V2, and the abbe number of the fourth lens element, V4, could be controlled to satisfy the equation as follows:

$$0 \leq |V2 - V4| \leq 10 \quad \text{Equation (10); or}$$

G23 and CTmin could be controlled to satisfy the equation as follows:

$$G23/CTmin \leq 1.6 \quad \text{Equation (11); or}$$

CTmin and the sum of the thickness of all five lens elements along the optical axis, ALT, could be controlled to satisfy the equation as follows:

$$ALT/CTmin \leq 9.5 \quad \text{Equation (12); or}$$

G23 and a back focal length of the optical imaging lens, i.e. the distance from the image-side surface of the fifth lens element to an image plane on the optical axis, BFL, could be controlled to satisfy the equation as follows:

$$3.9 \leq BFL/G23 \quad \text{Equation (13); or}$$

ALT and Gaa could be controlled to satisfy the equation as follows:

$$2.3 \leq ALT/Gaa \leq 3.6 \quad \text{Equation (14); or}$$

Dmax and Dmin could be controlled to satisfy the equation as follows:

$$2.6 \leq Dmax/CTmin \quad \text{Equation (15); or}$$

ALT and T2 could be controlled to satisfy the equation as follows:

$$ALT/T2 \leq 9.5 \quad \text{Equation (16); or}$$

ALT and G34 could be controlled to satisfy the equation as follows:

$$3.5 \leq ALT/G34 \leq 15 \quad \text{Equation (17).}$$

Aforesaid exemplary embodiments are not limited and could be selectively incorporated in other embodiments described herein.

Reference is now made to Equation (1). Gaa/T4 is composed by a parameter more likely to be shortened, i.e. T4 here, and a parameter less likely to be shortened, i.e. Gaa here. Therefore, considering the optical characters and manufacturing difficulty, satisfying Equation (1) would assist in configuring the values of T4 and Gaa properly.

Reference is now made to Equation (2). The negative refracting power and smaller effective diameter of the second lens element that provides great potential to shorten its thickness more than Gaa does, here the equation is designed. Therefore, considering the optical characters manufacturing difficulty, satisfying Equation (2) would assist in configuring the values of T2 and Gaa properly.

Reference is now made to Equation (3). The values of EFL and G23 are shortened along with the shortening of the length of the optical imaging lens; however, the shortening

of G23 is limited by the concave image-side surface of the second lens element. Therefore, considering the optical characters and manufacturing difficulty, satisfying Equation (3) would assist in configuring the values of G23 and EFL properly.

Reference is now made to Equations (4). The values of EFL and Dmax are shortened along with the shortening of the length of the optical imaging lens; however, the shortening of Dmax is limited by the process margin. Therefore, the value of EFL/Dmax would satisfy Equation (4). Preferably, the value of EFL/Dmax is suggested for a lower limit, such as 3.7.

Reference is now made to Equation (5). The values of T5 and CTmin are shortened along with the shortening of the length of the optical imaging lens; however, the shortening of T5 is limited by the greater effective diameter of the fifth lens element. Therefore, the value of T5/CTmin would satisfy Equation (5). Preferably, the value of T5/CTmin is suggested for an upper limit, such as 4.5.

Reference is now made to Equation (6). The values of G34 and Gaa are shortened along with the shortening of the length of the optical imaging lens; however, the shortening of G34 is limited by the concave object-side surface of the fourth lens element. Therefore, the value of Gaa/G34 would satisfy Equation (6). Preferably, the value of Gaa/G34 is suggested for a lower limit, such as 1.5.

Reference is now made to Equation (7). The values of CTmax and CTmin are shortened along with the shortening of the length of the optical imaging lens; however, the shortening of CTmin is limited by the process margin. Therefore, the value of CTmax/CTmin would satisfy Equation (7). Preferably, the value of CTmax/CTmin is suggested for a lower limit, such as 1.8.

Reference is now made to Equation (8). The values of EFL and T5 are shortened along with the shortening of the length of the optical imaging lens; however, the shortening of T5 is limited by the greater effective diameter of the fifth lens element. Therefore, the value of EFL/T5 would satisfy Equation (8). Preferably, the value of EFL/T5 is suggested for a lower limit, such as 3.8.

Reference is now made to Equation (9). The values of Gaa and G23 are shortened along with the shortening of the length of the optical imaging lens; however, the shortening of G23 is limited by the concave image-side surface of the second lens element. Therefore, the value of Gaa/G23 would satisfy Equation (9). Preferably, the value of Gaa/G23 is suggested for a lower limit, such as 1.0.

Reference is now made to Equation (10). Considering the performance to eliminate the chromatic aberration of the optical imaging lens by the second and fourth lens element with close abbe number and the rest lens elements, here the equation is designed.

Reference is now made to Equation (11). The values of CTmin and G23 are shortened along with the shortening of the length of the optical imaging lens; however, although the shortening of G23 is limited by the concave image-side surface of the second lens element, the potential to shorten CTmin is still less due to the process margin in the manufacturing process. Therefore, the value of G23/CTmin would satisfy Equation (11). Preferably, the value of G23/CTmin is suggested for a lower limit, such as 0.7.

Reference is now made to Equation (12). The values of ALT and CTmin are shortened along with the shortening of the length of the optical imaging lens; however, the shortening of CTmin is limited by the process margin. Therefore,

the value of ALT/CTmin would satisfy Equation (12). Preferably, the value of ALT/CTmin is suggested for a lower limit, such as 6.8.

Reference is now made to Equation (13). The values of BFL and G23 are shortened along with the shortening of the length of the optical imaging lens; however, although the shortening of G23 is limited by the concave image-side surface of the second lens element, the potential to shorten BFL is still less due to the process margin in the manufacturing process. Therefore, the value of BFL/G23 would satisfy Equation (13). Preferably, the value of BFL/G23 is suggested for an upper limit, such as 6.0.

Reference is now made to Equation (14). The values of ALT and Gaa are shortened along with the shortening of the length of the optical imaging lens. Therefore, considering the optical characters and manufacturing difficulty, satisfying Equation (14) would assist in configuring the values of ALT and Gaa properly.

Reference is now made to Equation (15). The values of Dmax and CTmin are shortened along with the shortening of the length of the optical imaging lens. Therefore, considering the optical characters and manufacturing difficulty, satisfying Equation (15) would assist in configuring the values of Dmax and CTmin properly. Preferably, the value of Dmax/CTmin is suggested for an upper limit, such as 4.6.

Reference is now made to Equation (16). The values of ALT and T2 are shortened along with the shortening of the length of the optical imaging lens; however, the shortening of ALT could be broadly contributed by not only the thickness of the second lens element but the thickness of the rest lens elements. Therefore, the value of ALT/T2 would satisfy Equation (16). Preferably, the value of ALT/T2 is suggested for a lower limit, such as 7.0.

Reference is now made to Equation (17). The values of G34 and ALT are shortened along with the shortening of the length of the optical imaging lens; however, the shortening of G34 is limited by the concave object-side surface of the fourth lens element. Therefore, considering the optical characters and manufacturing difficulty, satisfying Equation (17) would assist in configuring the values of G34 and ALT properly.

When implementing example embodiments, more details about the convex or concave surface structure may be incorporated for one specific lens element or broadly for plural lens elements to enhance the control for the system performance and/or resolution, as illustrated in the following embodiments. For example, the object-side surface of the third lens element comprises a concave portion in a vicinity of the optical axis, the image-side surface of the first lens element may comprise a convex portion in a vicinity of the optical axis, and/or the object-side surface of the second lens element comprises a convex portion in a vicinity of a periphery of the second lens element, etc. It is noted that the details listed here could be incorporated in example embodiments if no inconsistency occurs.

Several exemplary embodiments and associated optical data will now be provided for illustrating example embodiments of optical imaging lens with good optical characters and a shortened length. Reference is now made to FIGS. 2-5. FIG. 2 illustrates an example cross-sectional view of an optical imaging lens 1 having five lens elements of the optical imaging lens according to a first example embodiment. FIG. 3 shows example charts of longitudinal spherical aberration and other kinds of optical aberrations of the optical imaging lens 1 according to an example embodiment. FIG. 4 illustrates an example table of optical data of each lens element of the optical imaging lens 1 according to

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an example embodiment. FIG. 5 depicts an example table of aspherical data of the optical imaging lens 1 according to an example embodiment.

As shown in FIG. 2, the optical imaging lens 1 of the present embodiment comprises, in order from an object side A1 to an image side A2 along an optical axis, an aperture stop 100, a first lens element 110, a second lens element 120, a third lens element 130, a fourth lens element 140 and a fifth lens element 150. A filtering unit 160 and an image plane 170 of an image sensor are positioned at the image side A2 of the optical lens 1. Each of the first, second, third, fourth, fifth lens elements 110, 120, 130, 140, 150 and the filtering unit 160 comprises an object-side surface 111/121/131/141/151/161 facing toward the object side A1 and an image-side surface 112/122/132/142/152/162 facing toward the image side A2. The example embodiment of the filtering unit 160 illustrated is an IR cut filter (infrared cut filter) positioned between the fifth lens element 150 and an image plane 170. The filtering unit 160 selectively absorbs light with specific wavelength from the light passing optical imaging lens 1. For example, IR light is absorbed, and this will prohibit the IR light which is not seen by human eyes from producing an image on the image plane 170.

Exemplary embodiments of each lens element of the optical imaging lens 1 which may be constructed by plastic material will now be described with reference to the drawings.

An example embodiment of the first lens element 110 may have positive refracting power. The object-side surface 111 is a convex surface. The image-side surface 112 comprises a concave portion 1121 in a vicinity of the optical axis and a convex portion 1122 in a vicinity of a periphery of the first lens element 110.

An example embodiment of the second lens element 120 may have negative refracting power. The object-side surface 121 is a convex surface and the image-side surface 122 is a concave surface. The object-side surface 121 further comprises a convex portion 1211 in a vicinity of a periphery of the second lens element 120.

An example embodiment of the third lens element 130 may have positive refracting power. The object-side surface 131 is a concave surface comprising a concave portion 1311 in a vicinity of the optical axis and a concave portion 1312 in a vicinity of a periphery of the third lens element 130. The image-side surface 132 is a convex surface comprising a convex portion 1321 in a vicinity of a periphery of the third lens element 130.

An example embodiment of the fourth lens element 140 may have negative refracting power. The object-side surface 141 is a concave surface and the image-side surface 142 is a convex surface.

An example embodiment of the fifth lens element 150 may have positive refracting power. The object-side surface 151 comprises a convex portion 1511 in a vicinity of the optical axis and a concave portion 1512 in a vicinity of a periphery of the fifth lens element 150. The image-side surface 152 comprises a concave portion 1521 in a vicinity of the optical axis and a convex portion 1522 in a vicinity of a periphery of the fifth lens element 150.

In example embodiments, air gaps exist between the lens elements 110, 120, 130, 140, 150, the filtering unit 160 and the image plane 170 of the image sensor. For example, FIG. 1 illustrates the air gap d1 existing between the first lens element 110 and the second lens element 120, the air gap d2 existing between the second lens element 120 and the third lens element 130, the air gap d3 existing between the third lens element 130 and the fourth lens element 140, the air gap

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d4 existing between the fourth lens element 140 and the fifth lens element 150, the air gap d5 existing between the fifth lens element 150 and the filtering unit 160, and the air gap d6 existing between the filtering unit 160 and the image plane 170 of the image sensor. However, in other embodiments, any of the aforesaid air gaps may or may not exist. For example, the profiles of opposite surfaces of any two adjacent lens elements may correspond to each other, and in such situation, the air gap may not exist. The air gap d1 is denoted by G12, the air gap d2 is denoted by G23, the air gap d3 is denoted by G34, the air gap d4 is denoted by G45, and the sum of all air gaps d1, d2, d3 and d4 between the first and fifth lens elements 110, 150 is denoted by Gaa.

FIG. 4 depicts the optical characters of each lens elements in the optical imaging lens 1 of the present embodiment, wherein the values of T2, T4, T5, G23, G34, Gaa, CTmin, CTmax, Dmax, BFL, ALT, EFL, Gaa/T4, Gaa/T2, EFL/G23, EFL/Dmax, T5/CTmin, Gaa/G34, CTmax/CTmin, EFL/T5, Gaa/G23, |V2-V4|, G23/CTmin, ALT/CTmin, BFL/G23, ALT/Gaa, Dmax/CTmin, ALT/T2 and ALT/G34 are:

T2=0.23 (mm);  
T4=0.49 (mm);  
T5=0.84 (mm);  
G23=0.41 (mm);  
G34=0.25 (mm);  
Gaa=0.79 (mm);  
CTmin=0.23 (mm);  
CTmax=0.84 (mm);  
Dmax=0.84 (mm);  
BFL=1.53 (mm);  
ALT=2.79 (mm);  
EFL=3.97 (mm);  
Gaa/T4=1.60;  
Gaa/T2=3.44;  
EFL/G23=9.70;  
EFL/Dmax=4.71;  
T5/CTmin=3.65;  
Gaa/G34=3.11;  
CTmax/CTmin=3.65;  
EFL/T5=4.71;  
Gaa/G23=1.94;  
|V2-V4|=0.00;  
G23/CTmin=1.78;  
ALT/CTmin=12.10;  
BFL/G23=3.75;  
ALT/Gaa=3.52;  
Dmax/CTmin=3.65;  
ALT/T2=12.10;  
ALT/G34=10.97;

wherein the distance from the object-side surface 111 of the first lens element 110 to the image plane 170 along the optical axis is 5.11 mm, and the length of the optical imaging lens 1 is shortened.

The aspherical surfaces, including the object-side surface 111 and the image-side surface 112 of the first lens element 110, the object-side surface 121 and the image-side surface 122 of the second lens element 120, the object-side surface 131 and the image-side surface 132 of the third lens element 130, the object-side surface 141 and the image-side surface 142 of the fourth lens element 140, and the object-side surface 151 and the image-side surface 152 of the fifth lens element 150 are all defined by the following aspherical formula:

$$Z(Y) = \frac{Y^2}{R} / \left( 1 + \sqrt{1 - (1 + K) \frac{Y^2}{R^2}} \right) + \sum_{i=1}^n a_{2i} \times Y^{2i}$$

wherein,

R represents the radius of curvature of the surface of the lens element;

Z represents the depth of the aspherical surface (the perpendicular distance between the point of the aspherical surface at a distance Y from the optical axis and the tangent plane of the vertex on the optical axis of the aspherical surface);

Y represents the perpendicular distance between the point of the aspherical surface and the optical axis;

K represents a conic constant;

$a_{2i}$  represents an aspherical coefficient of  $2i^{th}$  level.

The values of each aspherical parameter are shown in FIG. 5.

As illustrated in FIG. 3, longitudinal spherical aberration (a), the curves of different wavelengths are closed to each other. This represents off-axis light with respect to these wavelengths is focused around an image point. From the vertical deviation of each curve shown therein, the offset of the off-axis light relative to the image point is within  $\pm 0.06$  mm. Therefore, the present embodiment improves the longitudinal spherical aberration with respect to different wavelengths.

Please refer to FIG. 3, astigmatism aberration in the sagittal direction (b) and astigmatism aberration in the tangential direction (c). The focus variation with respect to the three wavelengths in the whole field falls within  $\pm 0.05$  mm. This reflects the optical imaging lens 1 of the present embodiment eliminates aberration effectively. Additionally, the closed curves represents dispersion is improved.

Please refer to FIG. 3, distortion aberration (d), which showing the variation of the distortion aberration is within  $\pm 2\%$ . Such distortion aberration meets the requirement of acceptable image quality and shows the optical imaging lens 1 of the present embodiment could restrict the distortion aberration to raise the image quality even though the length of the optical imaging lens 1 is shortened to 5.11 mm.

Therefore, the optical imaging lens 1 of the present embodiment shows great characteristics in the longitudinal spherical aberration, astigmatism in the sagittal direction, astigmatism in the tangential direction, and distortion aberration. According to above illustration, the optical imaging lens 1 of the example embodiment indeed achieves great optical performance and the length of the optical imaging lens 1 is effectively shortened.

Reference is now made to FIGS. 6-9. FIG. 6 illustrates an example cross-sectional view of an optical imaging lens 2 having five lens elements of the optical imaging lens according to a second example embodiment. FIG. 7 shows example charts of longitudinal spherical aberration and other kinds of optical aberrations of the optical imaging lens 2 according to the second example embodiment. FIG. 8 shows an example table of optical data of each lens element of the optical imaging lens 2 according to the second example embodiment. FIG. 9 shows an example table of aspherical data of the optical imaging lens 2 according to the second example embodiment. The reference numbers labeled in the present embodiment are similar to those in the first embodiment for the similar elements, but here the reference numbers are initiated with 2, for example, reference number 231 for labeling the object-side surface of the third lens element 230, reference number 232 for labeling the image-side surface of the third lens element 230, etc.

As shown in FIG. 6, the optical imaging lens 2 of the present embodiment, in an order from an object side A1 to an image side A2 along an optical axis, comprises an aperture stop 200, the first lens element 210, a second lens

element 220, a third lens element 230, a fourth lens element 240 and a fifth lens element 250.

The differences between the second embodiment and the first embodiment are the radius of curvature and thickness of each lens element, the distance of each air gap and the surface shape of the image-side surface 212, but the configuration of the positive/negative refracting power of the first, second, third, fourth and fifth lens elements 210, 220, 230, 240 and 250 and configuration of the concave/convex shape of surfaces, comprising the object-side surfaces 211, 221, 231, 241, 251 facing to the object side A1 and the image-side surfaces 222, 232, 242, 252 facing to the image side A2, are similar to those in the first embodiment. Specifically, the image-side surface 212 of the first lens element 210 is a convex surface comprising a convex portion 2121 in a vicinity of a periphery of the first lens element 210. Please refer to FIG. 8 for the optical characteristics of each lens elements in the optical imaging lens 2 of the present embodiment, wherein the values of T2, T4, T5, G23, G34, Gaa, CTmin, CTmax, Dmax, BFL, ALT, EFL, Gaa/T4, Gaa/T2, EFL/G23, EFL/Dmax, T5/CTmin, Gaa/G34, CTmax/CTmin, EFL/T5, Gaa/G23, IV2-V4, G23/CTmin, ALT/CTmin, BFL/G23, ALT/Gaa, Dmax/CTmin, ALT/T2 and ALT/G34 are:

T2=0.26 (mm);  
T4=0.36 (mm);  
T5=0.98 (mm);  
G23=0.58 (mm);  
G34=0.21 (mm);  
Gaa=0.94 (mm);  
CTmin=0.26 (mm);  
CTmax=0.98 (mm);  
Dmax=0.98 (mm);  
BFL=1.48 (mm);  
ALT=2.72 (mm);  
EFL=4.10 (mm);  
Gaa/T4=2.65;  
Gaa/T2=3.62;  
EFL/G23=7.13;  
EFL/Dmax=4.18;  
T5/CTmin=3.75;  
Gaa/G34=4.44;  
CTmax/CTmin=3.75;  
EFL/T5=4.18;  
Gaa/G23=1.64;  
IV2-V4=0.00;  
G23/CTmin=2.20;  
ALT/CTmin=10.42;  
BFL/G23=2.57;  
ALT/Gaa=2.88;  
Dmax/CTmin=3.75;  
ALT/T2=10.42;  
ALT/G34=12.78;

wherein the distance from the object-side surface 211 of the first lens element 210 to the image plane 270 along the optical axis is 5.14 mm and the length of the optical imaging lens 2 is shortened.

As shown in FIG. 7, the optical imaging lens 2 of the present embodiment shows great characteristics in longitudinal spherical aberration (a), astigmatism in the sagittal direction (b), astigmatism in the tangential direction (c), and distortion aberration (d). Therefore, according to the above illustration, the optical imaging lens of the present embodiment indeed shows great optical performance and the length of the optical imaging lens 2 is effectively shortened.

Reference is now made to FIGS. 10-13. FIG. 10 illustrates an example cross-sectional view of an optical imaging lens

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3 having five lens elements of the optical imaging lens according to a third example embodiment. FIG. 11 shows example charts of longitudinal spherical aberration and other kinds of optical aberrations of the optical imaging lens 3 according to the third example embodiment. FIG. 12 shows an example table of optical data of each lens element of the optical imaging lens 3 according to the third example embodiment. FIG. 13 shows an example table of aspherical data of the optical imaging lens 3 according to the third example embodiment. The reference numbers labeled in the present embodiment are similar to those in the first embodiment for the similar elements, but here the reference numbers are initialed with 3, for example, reference number 331 for labeling the object-side surface of the third lens element 330, reference number 332 for labeling the image-side surface of the third lens element 330, etc.

As shown in FIG. 10, the optical imaging lens 3 of the present embodiment, in an order from an object side A1 to an image side A2 along an optical axis, comprises an aperture stop 300, the first lens element 310, a second lens element 320, a third lens element 330, a fourth lens element 340 and a fifth lens element 350.

The differences between the third embodiment and the second embodiment are the radius of curvature and thickness of each lens element, the distance of each air gap and the surface shape of the object-side surface 321, but the configuration of the positive/negative refracting power of the first, second, third, fourth and fifth lens elements 310, 320, 330, 340, 350 and configuration of the concave/convex shape of surfaces, comprising the object-side surfaces 311, 331, 341, 351 facing to the object side A1 and the image-side surfaces 312, 322, 332, 342, 352 facing to the image side A2, are similar to those in the second embodiment. Specifically, the object-side surface 321 of the second lens element 320 comprises a convex portion 3211 in a vicinity of the optical axis and a concave portion 3212 in a vicinity of a periphery of the second lens element 320. Please refer to FIG. 12 for the optical characteristics of each lens elements in the optical imaging lens 3 of the present embodiment, wherein the values of T2, T4, T5, G23, G34, Gaa, CTmin, CTmax, Dmax, BFL, ALT, EFL, Gaa/T4, Gaa/T2, EFL/G23, EFL/Dmax, T5/CTmin, Gaa/G34, CTmax/CTmin, EFL/T5, Gaa/G23, |V2-V4|, G23/CTmin, ALT/CTmin, BFL/G23, ALT/Gaa, Dmax/CTmin, ALT/T2 and ALT/G34 are:

T2=0.23 (mm);  
T4=0.47 (mm);  
T5=0.94 (mm);  
G23=0.27 (mm);  
G34=0.32 (mm);  
Gaa=0.76 (mm);  
CTmin=0.23 (mm);  
CTmax=0.94 (mm);  
Dmax=0.94 (mm);  
BFL=1.51 (mm);  
ALT=2.88 (mm);  
EFL=4.00 (mm);  
Gaa/T4=1.63;  
Gaa/T2=3.35;  
EFL/G23=14.99;  
EFL/Dmax=4.26;  
T5/CTmin=4.13;  
Gaa/G34=2.38;  
CTmax/CTmin=4.13;  
EFL/T5=4.26;  
Gaa/G23=2.86;  
|V2-V4|=0.00;  
G23/CTmin=1.17;

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ALT/CTmin=12.67;  
BFL/G23=5.67;  
ALT/Gaa=3.78;  
Dmax/CTmin=4.13;  
ALT/T2=12.67;  
ALT/G34=9.01;

wherein the distance from the object-side surface 311 of the first lens element 310 to the image plane 370 along the optical axis is 5.16 mm and the length of the optical imaging lens 3 is shortened.

As shown in FIG. 11, the optical imaging lens 3 of the present embodiment shows great characteristics in longitudinal spherical aberration (a), astigmatism in the sagittal direction (b), astigmatism in the tangential direction (c), and distortion aberration (d). Therefore, according to the above illustration, the optical imaging lens of the present embodiment indeed shows great optical performance and the length of the optical imaging lens 3 is effectively shortened.

Reference is now made to FIGS. 14-17. FIG. 14 illustrates an example cross-sectional view of an optical imaging lens 4 having five lens elements of the optical imaging lens according to a fourth example embodiment. FIG. 15 shows example charts of longitudinal spherical aberration and other kinds of optical aberrations of the optical imaging lens 4 according to the fourth embodiment. FIG. 16 shows an example table of optical data of each lens element of the optical imaging lens 4 according to the fourth example embodiment. FIG. 17 shows an example table of aspherical data of the optical imaging lens 4 according to the fourth example embodiment. The reference numbers labeled in the present embodiment are similar to those in the first embodiment for the similar elements, but here the reference numbers are initialed with 4, for example, reference number 431 for labeling the object-side surface of the third lens element 430, reference number 432 for labeling the image-side surface of the third lens element 430, etc.

As shown in FIG. 14, the optical imaging lens 4 of the present embodiment, in an order from an object side A1 to an image side A2 along an optical axis, comprises an aperture stop 400, the first lens element 410, a second lens element 420, a third lens element 430, a fourth lens element 440 and a fifth lens element 450.

The differences between the fourth embodiment and the first embodiment are the radius of curvature and thickness of each lens element and the distance of each air gap, but the configuration of the positive/negative refracting power of the first, second, third, fourth and fifth lens elements 410, 420, 430, 440, 450 and configuration of the concave/convex shape of surfaces, comprising the object-side surfaces 411, 421, 431, 441, 451 facing to the object side A1 and the image-side surfaces 412, 422, 432, 442, 452 facing to the image side A2, are similar to those in the first embodiment. Please refer to FIG. 16 for the optical characteristics of each lens elements in the optical imaging lens 4 of the present embodiment, wherein the values of T2, T4, T5, G23, G34, Gaa, CTmin, CTmax, Dmax, BFL, ALT, EFL, Gaa/T4, Gaa/T2, EFL/G23, EFL/Dmax, T5/CTmin, Gaa/G34, CTmax/CTmin, EFL/T5, Gaa/G23, |V2-V4|, G23/CTmin, ALT/CTmin, BFL/G23, ALT/Gaa, Dmax/CTmin, ALT/T2 and ALT/G34 are:

T2=0.24 (mm);  
T4=0.29 (mm);  
T5=0.90 (mm);  
G23=0.50 (mm);  
G34=0.26 (mm);  
Gaa=1.05 (mm);  
CTmin=0.24 (mm);

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CTmax=0.90 (mm);  
 Dmax=0.90 (mm);  
 BFL=1.48 (mm);  
 ALT=2.62 (mm);  
 EFL=4.06 (mm);  
 Gaa/T4=3.60;  
 Gaa/T2=4.29;  
 EFL/G23=8.06;  
 EFL/Dmax=4.52;  
 T5/CTmin=3.67;  
 Gaa/G34=3.99;  
 CTmax/CTmin=3.67;  
 EFL/T5=4.52;  
 Gaa/G23=2.09;  
 |V2-V4|=0.00;  
 G23/CTmin=2.06;  
 ALT/CTmin=10.71;  
 BFL/G23=2.93;  
 ALT/Gaa=2.50;  
 Dmax/CTmin=3.67;  
 ALT/T2=10.71;  
 ALT/G34=9.96;

wherein the distance from the object-side surface **411** of the first lens element **410** to the image plane **470** along the optical axis is 5.15 mm and the length of the optical imaging lens **4** is shortened.

As shown in FIG. **15**, the optical imaging lens **4** of the present embodiment shows great characteristics in longitudinal spherical aberration (a), astigmatism in the sagittal direction (b), astigmatism in the tangential direction (c), and distortion aberration (d). Therefore, according to the above illustration, the optical imaging lens of the present embodiment indeed shows great optical performance and the length of the optical imaging lens **4** is effectively shortened.

Reference is now made to FIGS. **18-21**. FIG. **18** illustrates an example cross-sectional view of an optical imaging lens **5** having five lens elements of the optical imaging lens according to a fifth example embodiment. FIG. **19** shows example charts of longitudinal spherical aberration and other kinds of optical aberrations of the optical imaging lens **5** according to the fifth embodiment. FIG. **20** shows an example table of optical data of each lens element of the optical imaging lens **5** according to the fifth example embodiment. FIG. **21** shows an example table of aspherical data of the optical imaging lens **5** according to the fifth example embodiment. The reference numbers labeled in the present embodiment are similar to those in the first embodiment for the similar elements, but here the reference numbers are initialed with **5**, for example, reference number **531** for labeling the object-side surface of the third lens element **530**, reference number **532** for labeling the image-side surface of the third lens element **530**, etc.

As shown in FIG. **18**, the optical imaging lens **5** of the present embodiment, in an order from an object side A1 to an image side A2 along an optical axis, comprises an aperture stop **500**, the first lens element **510**, a second lens element **520**, a third lens element **530**, a fourth lens element **540** and a fifth lens element **550**.

The differences between the fifth embodiment and the second embodiment are the radius of curvature and thickness of each lens element, the distance of each air gap and the spherical surface shape of the object-side surface **531** and the image-side surface **532** of the third lens element **530**, but the configuration of the positive/negative refracting power of the first, second, third, fourth and fifth lens elements **510**, **520**, **530**, **540**, **550** and configuration of the concave/convex shape of surfaces, comprising the object-

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side surfaces **511**, **521**, **531**, **541**, **551** facing to the object side A1 and the image-side surfaces **512**, **522**, **532**, **542**, **552** facing to the image side A2, are similar to those in the first embodiment. Please refer to FIG. **20** for the optical characteristics of each lens elements in the optical imaging lens **5** of the present embodiment, wherein the values of T2, T4, T5, G23, G34, Gaa, CTmin, CTmax, Dmax, BFL, ALT, EFL, Gaa/T4, Gaa/T2, EFL/G23, EFL/Dmax, T5/CTmin, Gaa/G34, CTmax/CTmin, EFL/T5, Gaa/G23, |V2-V4|, G23/CTmin, ALT/CTmin, BFL/G23, ALT/Gaa, Dmax/CTmin, ALT/T2 and ALT/G34 are:

T2=0.30 (mm);  
 T4=0.35 (mm);  
 T5=0.79 (mm);  
 G23=0.32 (mm);  
 G34=0.51 (mm);  
 Gaa=1.01 (mm);  
 CTmin=0.30 (mm);  
 CTmax=0.79 (mm);  
 Dmax=0.79 (mm);  
 BFL=1.60 (mm);  
 ALT=2.52 (mm);  
 EFL=4.30 (mm);  
 Gaa/T4=2.90;  
 Gaa/T2=3.38;  
 EFL/G23=13.64;  
 EFL/Dmax=5.44;  
 T5/CTmin=2.63;  
 Gaa/G34=1.99;  
 CTmax/CTmin=2.63;  
 EFL/T5=5.44;  
 Gaa/G23=3.21;  
 |V2-V4|=6.77;  
 G23/CTmin=1.05;  
 ALT/CTmin=8.40;  
 BFL/G23=5.08;  
 ALT/Gaa=2.49;  
 Dmax/CTmin=2.63;  
 ALT/T2=8.40;  
 ALT/G34=4.96;

wherein the distance from the object-side surface **511** of the first lens element **510** to the image plane **570** along the optical axis is 5.13 mm and the length of the optical imaging lens **5** is shortened.

As shown in FIG. **19**, the optical imaging lens **5** of the present embodiment shows great characteristics in longitudinal spherical aberration (a), astigmatism in the sagittal direction (b), astigmatism in the tangential direction (c), and distortion aberration (d). Therefore, according to the above illustration, the optical imaging lens of the present embodiment indeed shows great optical performance and the length of the optical imaging lens **5** is effectively shortened.

Reference is now made to FIGS. **22-25**. FIG. **22** illustrates an example cross-sectional view of an optical imaging lens **6** having five lens elements of the optical imaging lens according to a sixth example embodiment. FIG. **23** shows example charts of longitudinal spherical aberration and other kinds of optical aberrations of the optical imaging lens **6** according to the sixth embodiment. FIG. **24** shows an example table of optical data of each lens element of the optical imaging lens **6** according to the sixth example embodiment. FIG. **25** shows an example table of aspherical data of the optical imaging lens **6** according to the sixth example embodiment. The reference numbers labeled in the present embodiment are similar to those in the first embodiment for the similar elements, but here the reference numbers are initialed with **6**, for example, reference number **631**

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for labeling the object-side surface of the third lens element **630**, reference number **632** for labeling the image-side surface of the third lens element **630**, etc.

As shown in FIG. **22**, the optical imaging lens **6** of the present embodiment, in an order from an object side A1 to an image side A2 along an optical axis, comprises an aperture stop **600**, the first lens element **610**, a second lens element **620**, a third lens element **630**, a fourth lens element **640** and a fifth lens element **650**.

The differences between the sixth embodiment and the fifth embodiment are the radius of curvature and thickness of each lens element, the distance of each air gap and the positive/negative refracting power of the fifth lens element **650**, but the configuration of the positive/negative refracting power of the first, second, third and fourth lens elements **610**, **620**, **630**, **640** and configuration of the concave/convex shape of surfaces, comprising the object-side surfaces **611**, **621**, **631**, **641**, **651** facing to the object side A1 and the image-side surfaces **612**, **622**, **632**, **642**, **652** facing to the image side A2, are similar to those in the fifth embodiment. Specifically, the fifth lens element **650** has negative refracting power. Please refer to FIG. **24** for the optical characteristics of each lens elements in the optical imaging lens **6** of the present embodiment, wherein the values of T2, T4, T5, G23, G34, Gaa, CTmin, CTmax, Dmax, BFL, ALT, EFL, Gaa/T4, Gaa/T2, EFL/G23, EFL/Dmax, T5/CTmin, Gaa/G34, CTmax/CTmin, EFL/T5, Gaa/G23, |V2-V4|, G23/CTmin, ALT/CTmin, BFL/G23, ALT/Gaa, Dmax/CTmin, ALT/T2 and ALT/G34 are:

T2=0.35 (mm);  
T4=0.35 (mm);  
T5=0.74 (mm);  
G23=0.34 (mm);  
G34=0.49 (mm);  
Gaa=1.08 (mm);  
CTmin=0.35 (mm);  
CTmax=0.74 (mm);  
Dmax=0.74 (mm);  
BFL=1.60 (mm);  
ALT=2.54 (mm);  
EFL=4.30 (mm);  
Gaa/T4=3.09;  
Gaa/T2=3.14;  
EFL/G23=12.49;  
EFL/Dmax=5.78;  
T5/CTmin=2.15;  
Gaa/G34=2.21;  
CTmax/CTmin=2.15;  
EFL/T5=5.78;  
Gaa/G23=3.15;  
|V2-V4|=6.77;  
G23/CTmin=1.00;  
ALT/CTmin=7.37;  
BFL/G23=4.65;  
ALT/Gaa=2.35;  
Dmax/CTmin=2.15;  
ALT/T2=7.37;  
ALT/G34=5.19;

wherein the distance from the object-side surface **611** of the first lens element **610** to the image plane **670** along the optical axis is 5.23 mm and the length of the optical imaging lens **6** is shortened.

As shown in FIG. **23**, the optical imaging lens **6** of the present embodiment shows great characteristics in longitudinal spherical aberration (a), astigmatism in the sagittal direction (b), astigmatism in the tangential direction (c), and distortion aberration (d). Therefore, according to the above

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illustration, the optical imaging lens of the present embodiment indeed shows great optical performance and the length of the optical imaging lens **6** is effectively shortened.

Reference is now made to FIGS. **26-29**. FIG. **26** illustrates an example cross-sectional view of an optical imaging lens **7** having five lens elements of the optical imaging lens according to a seventh example embodiment. FIG. **27** shows example charts of longitudinal spherical aberration and other kinds of optical aberrations of the optical imaging lens **7** according to the seventh embodiment. FIG. **28** shows an example table of optical data of each lens element of the optical imaging lens **7** according to the seventh example embodiment. FIG. **29** shows an example table of aspherical data of the optical imaging lens **7** according to the seventh example embodiment. The reference numbers labeled in the present embodiment are similar to those in the first embodiment for the similar elements, but here the reference numbers are initialed with **7**, for example, reference number **731** for labeling the object-side surface of the third lens element **730**, reference number **732** for labeling the image-side surface of the third lens element **730**, etc.

As shown in FIG. **26**, the optical imaging lens **7** of the present embodiment, in an order from an object side A1 to an image side A2 along an optical axis, comprises an aperture stop **700**, the first lens element **710**, a second lens element **720**, a third lens element **730**, a fourth lens element **740** and a fifth lens element **750**.

The differences between the seventh embodiment and the second embodiment are the radius of curvature and thickness of each lens element and the distance of each air gap, but the configuration of the positive/negative refracting power of the first, second, third, fourth and fifth lens elements **710**, **720**, **730**, **740**, **750** and configuration of the concave/convex shape of surfaces, comprising the object-side surfaces **711**, **721**, **731**, **741**, **751** facing to the object side A1 and the image-side surfaces **712**, **722**, **732**, **742**, **752** facing to the image side A2, are similar to those in the second embodiment. Please refer to FIG. **28** for the optical characteristics of each lens elements in the optical imaging lens **7** of the present embodiment, wherein the values of T2, T4, T5, G23, G34, Gaa, CTmin, CTmax, Dmax, BFL, ALT, EFL, Gaa/T4, Gaa/T2, EFL/G23, EFL/Dmax, T5/CTmin, Gaa/G34, CTmax/CTmin, EFL/T5, Gaa/G23, |V2-V4|, G23/CTmin, ALT/CTmin, BFL/G23, ALT/Gaa, Dmax/CTmin, ALT/T2 and ALT/G34 are:

T2=0.31 (mm);  
T4=0.43 (mm);  
T5=0.91 (mm);  
G23=0.40 (mm);  
G34=0.22 (mm);  
Gaa=0.72 (mm);  
CTmin=0.31 (mm);  
CTmax=0.91 (mm);  
Dmax=0.91 (mm);  
BFL=1.58 (mm);  
ALT=2.85 (mm);  
EFL=4.00 (mm);  
Gaa/T4=1.67;  
Gaa/T2=2.30;  
EFL/G23=9.99;  
EFL/Dmax=4.40;  
T5/CTmin=2.92;  
Gaa/G34=3.30;  
CTmax/CTmin=2.92;  
EFL/T5=4.40;  
Gaa/G23=1.79;  
|V2-V4|=0.00;

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G23/CTmin=1.28;  
 ALT/CTmin=9.15;  
 BFL/G23=3.94;  
 ALT/Gaa=3.97;  
 Dmax/CTmin=2.92;  
 ALT/T2=9.15;  
 ALT/G34=13.11;

wherein the distance from the object-side surface **711** of the first lens element **710** to the image plane **770** along the optical axis is 5.15 mm and the length of the optical imaging lens **7** is shortened.

As shown in FIG. **27**, the optical imaging lens **7** of the present embodiment shows great characteristics in longitudinal spherical aberration (a), astigmatism in the sagittal direction (b), astigmatism in the tangential direction (c), and distortion aberration (d). Therefore, according to the above illustration, the optical imaging lens of the present embodiment indeed shows great optical performance and the length of the optical imaging lens **7** is effectively shortened.

Please refer to FIG. **30**, which shows the values of T2, T4, T5, G23, G34, Gaa, CTmin, CTmax, Dmax, BFL, ALT, EFL, Gaa/T4, Gaa/T2, EFL/G23, EFL/Dmax, T5/CTmin, Gaa/G34, CTmax/CTmin, EFL/T5, Gaa/G23, |V2-V4|, G23/CTmin, ALT/CTmin, BFL/G23, ALT/Gaa, Dmax/CTmin, ALT/T2 and ALT/G34 of all seventh embodiments, and it is clear that the optical imaging lens of the present invention satisfy the Equations (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12), (13), (14), (15), (16) and/or (17).

Reference is now made to FIG. **31**, which illustrates an example structural view of a first embodiment of mobile device **20** applying an aforesaid optical imaging lens. The mobile device **20** comprises a housing **21** and a photography module **22** positioned in the housing **21**. Examples of the mobile device **20** may be, but are not limited to, a mobile phone, a camera, a tablet computer, a personal digital assistant (PDA), etc.

As shown in FIG. **31**, the photography module **22** may comprise an aforesaid optical imaging lens with five lens elements, for example the optical imaging lens **1** of the first embodiment, a lens barrel **23** for positioning the optical imaging lens **1**, a module housing unit **24** for positioning the lens barrel **23**, a substrate **172** for positioning the module housing unit **24**, and an image sensor **171** which is positioned at an image side of the optical imaging lens **1**. The image plane **170** is formed on the image sensor **171**.

In some other example embodiments, the structure of the filtering unit **160** may be omitted. In some example embodiments, the housing **21**, the lens barrel **23**, and/or the module housing unit **24** may be integrated into a single component or assembled by multiple components. In some example embodiments, the image sensor **171** used in the present embodiment is directly attached to a substrate **172** in the form of a chip on board (COB) package, and such package is different from traditional chip scale packages (CSP) since COB package does not require a cover glass before the image sensor **171** in the optical imaging lens **1**. Aforesaid exemplary embodiments are not limited to this package type and could be selectively incorporated in other described embodiments.

The five lens elements **110**, **120**, **130**, **140**, **150** are positioned in the lens barrel **23** in the way of separated by an air gap between any two adjacent lens elements.

The module housing unit **24** comprises a lens backseat **2401** for positioning the lens barrel **23** and an image sensor base **2406** positioned between the lens backseat **2401** and the image sensor **171**. The lens barrel **23** and the lens backseat **2401** are positioned along a same axis I-I', and the

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lens backseat **2401** is close to the outside of the lens barrel **23**. The image sensor base **2406** is exemplarily close to the lens backseat **2401** here. The image sensor base **2406** could be optionally omitted in some other embodiments of the present invention.

Because the length of the optical imaging lens **1** is merely 5.11 mm, the size of the mobile device **20** may be quite small. Therefore, the embodiments described herein meet the market demand for smaller sized product designs.

Reference is now made to FIG. **32**, which shows another structural view of a second embodiment of mobile device **20'** applying the aforesaid optical imaging lens **1**. One difference between the mobile device **20'** and the mobile device **20** may be the lens backseat **2401** comprising a first seat unit **2402**, a second seat unit **2403**, a coil **2404** and a magnetic unit **2405**. The first seat unit **2402** is close to the outside of the lens barrel **23**, and positioned along an axis I-I', and the second seat unit **2403** is around the outside of the first seat unit **2402** and positioned along with the axis I-I'. The coil **2404** is positioned between the first seat unit **2402** and the inside of the second seat unit **2403**. The magnetic unit **2405** is positioned between the outside of the coil **2404** and the inside of the second seat unit **2403**.

The lens barrel **23** and the optical imaging lens **1** positioned therein are driven by the first seat unit **2402** for moving along the axis I-I'. The rest structure of the mobile device **20'** is similar to the mobile device **20**.

Similarly, because the length of the optical imaging lens **1**, 5.11 mm, is shortened, the mobile device **20'** may be designed with a smaller size and meanwhile good optical performance is still provided. Therefore, the present embodiment meets the demand of small sized product design and the request of the market.

According to above illustration, it is clear that the mobile device and the optical imaging lens thereof in example embodiments, through controlling the detail structure and/or reflection power of the lens elements, the length of the optical imaging lens is effectively shortened and meanwhile good optical characters are still provided.

While various embodiments in accordance with the disclosed principles been described above, it should be understood that they are presented by way of example only, and are not limiting. Thus, the breadth and scope of exemplary embodiment(s) should not be limited by any of the above-described embodiments, but should be defined only in accordance with the claims and their equivalents issuing from this disclosure. Furthermore, the above advantages and features are provided in described embodiments, but shall not limit the application of such issued claims to processes and structures accomplishing any or all of the above advantages.

Additionally, the section headings herein are provided for consistency with the suggestions under 37 C.F.R. 1.77 or otherwise to provide organizational cues. These headings shall not limit or characterize the invention(s) set out in any claims that may issue from this disclosure. Specifically, a description of a technology in the "Background" is not to be construed as an admission that technology is prior art to any invention(s) in this disclosure. Furthermore, any reference in this disclosure to "invention" in the singular should not be used to argue that there is only a single point of novelty in this disclosure. Multiple inventions may be set forth according to the limitations of the multiple claims issuing from this disclosure, and such claims accordingly define the invention(s), and their equivalents, that are protected thereby. In all instances, the scope of such claims shall be considered on

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their own merits in light of this disclosure, but should not be constrained by the headings herein.

What is claimed is:

1. An optical imaging lens, sequentially from an object side to an image side along an optical axis, comprising an aperture stop, first, second, third, fourth and fifth lens elements, each of said first, second, third, fourth and fifth lens elements having an object-side surface facing toward the object side and an image-side surface facing toward the image side, wherein:

said first lens element has positive refracting power, and said image-side surface thereof comprises a convex portion in a vicinity of a periphery of the first lens element;

said second lens element has negative refracting power, and said image-side surface thereof is a concave surface;

said object-side surface of said third lens element comprises a concave portion in a vicinity of a periphery of the third lens element, and said image-side surface of said third lens element comprises a convex portion in a vicinity of a periphery of the third lens element;

said fourth lens element has negative refracting power, and said object-side surface of said fourth lens element is a concave surface;

said image-side surface of said fifth lens element comprises a concave portion in a vicinity of the optical axis and a convex portion in a vicinity of a periphery of the fifth lens element;

a central thickness of the third lens element along the optical axis is thicker than a central thickness of the fourth lens element along the optical axis;

a central thickness of the fifth lens element along the optical axis is thicker than a central thickness of the third lens element along the optical axis; and

the optical imaging lens as a whole comprises only the five lens elements having refracting power;

an air gap between the third lens element and the fourth lens element along the optical axis is G34, the sum of the thickness of all five lens elements along the optical axis is ALT, and ALT and G34 satisfy the equation:

$$3.5 \leq ALT/G34 \leq 15;$$

an air gap between the second lens element and the third lens element along the optical axis is G23, an effective focal length is EFL, and G23 and EFL satisfy the equation:

$$7 \leq EFL/G23 \leq 16.$$

2. The optical imaging lens according to claim 1, wherein a central thickness of the fourth lens element along the optical axis is T4, the sum of all four air gaps from the first lens element to the fifth lens element along the optical axis is Gaa, and T4 and Gaa satisfy the equation:

$$1.6 \leq Gaa/T4 \leq 3.6;$$

wherein said object-side surface of said third lens element comprises a concave portion in a vicinity of the optical axis; and

wherein there is an air gap between said first lens element and said second lens element along the optical axis.

3. The optical imaging lens according to claim 2, wherein a back focal length of the optical imaging lens, i.e. the distance from the image-side surface of the fifth lens element to an image plane on the optical axis, is BFL, and G23 and BFL satisfy the equation:

$$3.9 \leq BFL/G23.$$

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4. The optical imaging lens according to claim 3, wherein the maximum of the nine values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements on the optical axis and the four air gaps between any two adjacent lens elements of the first, second, third, fourth and fifth lens elements on the optical axis is Dmax, and EFL and Dmax satisfy the equation:

$$EFL/Dmax \leq 5.5.$$

5. The optical imaging lens according to claim 4, wherein a central thickness of the fifth lens element along the optical axis is T5, the minimum of the five values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements along the optical axis is CTmin, and T5 and CTmin satisfy the equation:

$$2.6 \leq T5/CTmin.$$

6. The optical imaging lens according to claim 3, wherein G34 and Gaa satisfy the equation:

$$Gaa/G34 \leq 3.75.$$

7. The optical imaging lens according to claim 6, wherein the maximum of the five values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements along the optical axis is CTmax, the minimum of the five values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements is CTmin, and CTmax and CTmin satisfy the equation:

$$CTmax/CTmin \leq 3.1; \text{ and}$$

said image-side surface of said first lens element comprises a convex portion in a vicinity of the optical axis.

8. The optical imaging lens according to claim 3, wherein a central thickness of the second lens element along the optical axis is T2, and T2 and Gaa satisfy the equation:

$$2.3 \leq Gaa/T2 \leq 4.3.$$

9. The optical imaging lens according to claim 8, wherein a central thickness of the fifth lens element along the optical axis is T5, an effective focal length is EFL, and T5 and EFL satisfy the equation:

$$EFL/T5 \leq 6.0.$$

10. The optical imaging lens according to claim 9, wherein G23 and Gaa satisfy the equation:

$$Gaa/G23 \leq 2.6.$$

11. The optical imaging lens according to claim 10, wherein the abbe number of the second lens element is V2, the abbe number of the fourth lens element is V4, and V2 and V4 satisfy the equation:

$$0 \leq |V2 - V4| \leq 10.$$

12. The optical imaging lens according to claim 3, wherein the minimum of the five values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements is CTmin, and G23 and CTmin satisfy the equation:

$$G23/CTmin \leq 1.6.$$

13. The optical imaging lens according to claim 12, wherein ALT and CTmin satisfy the equation:

$$ALT/CTmin \leq 9.5.$$

14. The optical imaging lens according to claim 2, wherein said image-side surface of said first lens element comprises a convex portion in a vicinity of the optical axis.

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15. The optical imaging lens according to claim 14, wherein ALT and Gaa satisfy the equation:

$$2.3 \leq ALT/Gaa \leq 3.6.$$

16. The optical imaging lens according to claim 15, the minimum of the five values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements is CTmin, the maximum of the nine values comprising the five lens thicknesses of the first, second, third, fourth and fifth lens elements on the optical axis and the four air gaps between any two adjacent lens elements of the first, second, third, fourth and fifth lens elements on the optical axis is Dmax, and CTmin and Dmax satisfy the equation:

$$2.6 \leq Dmax/CTmin; \text{ and}$$

said object-side surface of said second lens element comprises a convex portion in a vicinity of a periphery of the second lens element.

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17. The optical imaging lens according to claim 14, wherein a central thickness of the second lens element along the optical axis is T2, and T2 and ALT satisfy the equation:

$$ALT/T2 \leq 9.5.$$

18. A mobile device, comprising:

a housing; and

a photography module positioned in the housing and comprising:

the optical imaging lens as claimed in claim 1;

a lens barrel for positioning the optical imaging lens;

a module housing unit for positioning the lens barrel;

and

an image sensor positioned at the image side of the optical imaging lens.

\* \* \* \* \*